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# Forecasting Research

**Forecasting Research Division**
**Technical Report No.78**

## UPGRADING OF THE LIMITED AREA MODEL PHYSICS

**by**
**O.M. Hammon**
**15 November 1993**

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## 1.UPGRADING OF THE LIMITED AREA MODEL

**Trial period 08/09/93 - 30/10/93**

### 1. Introduction

A trial forecast of the limited area model was rerun daily during this period from DT00Z in parallel with the operational forecast. Both versions had a twelve hour cycle of assimilations starting from a reconfiguration of the operational global analysis. The trial package contained the following changes;

(i) the convection scheme was called less frequently, i.e. every other timestep.

(ii) a revised version of the rapidly mixing boundary layer including new interpolation for $T_{1.5}$, $q_{1.5}$ and $v_{10}$.

(iii) fully divergent treatment of cloud ice and changed threshold for formation of precipitation.

| operational | new |
|---|---|
| $0.8 \times 10^{-3}$ both land and sea | $0.8 \times 10^{-3}$ land |
| | $0.2 \times 10^{-3}$ sea |

(iv)although the operational cloud scheme was retained, the critical humidity thresholds were altered as shown below;

| level | operational | trial |
|---|---|---|
| 1 | .925 | .95 |
| 2 | .925 | .90 |
| 3 | .925 | .85 |
| 4 | .85 | .85 |

(v) a correction to the evaporation of precipitation (approx. half previous rate).

(vi) maximal overlap of contiguous cloud in long wave instead of random overlap.

In addition, two extra old cases were rerun;
(i) a winter snow case, DT00Z 24/01/93;
(ii) a summer thunderstorm case, DT12Z 08/06/93.

### 2. Subjective Assessment of continuous trial during Sept/Oct.

45 trial forecasts during the period September 8th to October 15th 1993 were assessed by comparison with the corresponding operational limited area forecasts. Generally the differences between the rival forecasts were small and not very significant. Mainly we were looking at small differences in low cloud and very light precipitation. The forecast differences discussed in this note are not dramatic but they represent the largest differences seen in this trial.

**a) Low cloud differences.**

Due to the changes in the critical humidities in the boundary layer alone, we would expect a small reduction in the amount of cloud at model level 1 predicted by the trial forecast and a slight increase at levels 2,3 and 4. However, the trial forecast of low cloud was also affected by the treatment of cloud ice and other changes to the boundary layer. Although a small reduction in level 1 cloud was noted over a relatively warm Europe, there was also an increase in cloudy areas over cold areas in Canada and Greenland, especially in areas where snow was predicted. This increase in level 1 cloud over icy land is due to the new treatment of cloud ice.

The trial T+36 forecast of mean sea level pressure and total precipitation rate verifying at DT 12Z 11/10/93 is shown in Figure 1. The main feature of interest is the depression centred over the Hudson Strait and the area of snow predicted over Canada. The amount of level 1 (ETA=0.997) cloud predicted by the trial and operational forecasts at T+36 are compared in Figures 2a and 2b respectively. The shaded area denotes more than 70% of cloud. The trial forecast(Figure 2a) has a much larger area of level 1 cloud over Canada associated with the wintry precipitation. This increase in level 1 cloud in cloudy areas in sub-freezing areas was a regular difference in the October forecasts.

Although occasional differences in low cloud forecasts over the U.K. and the North Sea were noted there was no consistent bias between the two versions, i.e. sometimes the trial predicted more low cloud, sometimes less.

An example of the small differences in low cloud predicted by the trial and operational forecasts can be seen by comparing Figures 3a and 3b respectively. The output shows medium and low cloud > 4 octas. In the trial cloud forecast for T+12, verifying at 12Z 11/09/93 (Figure 3a), low cloud was confined to Northern Scotland and the northern North Sea. The operational cloud forecast, (Figure 3b), predicted low cloud further south over the North Sea and also over Northeast England. This extra low cloud was at model level 2, as shown in Figure 4b. A comparison of the trial and operational forecast tephigrams for T+12 for Boulmer (Figures 5a and 5b respectively) shows the operational ascent to be slightly moister at 970mb. The verifying observations for this time are shown in the British Isles chart, Figure 6a, and these show that the low cloud and sea fog was confined further north to the coast of Northern Scotland exposed to easterly winds off the sea. The radiosonde ascent for Boulmer at 11Z, Figure 6b, was fairly dry, with very little low cloud. In this case the trial forecast was better.

Low cloud differences over the sea were also variable; some extra small areas of low cloud, base 3000-5000ft, were noticed in trial forecasts mainly in colder airmasses with cloud temperatures below freezing, with occasional decreases in amount over the warmer sea.

**b) Large scale rainfall**

Frontal rainfall was generally unaffected although some peak accumulations were 1-3mm less in the trial forecasts. The trial precipitation forecasts tended to be slightly spottier over the sea. A typical example of this can be seen by comparing the trial and operational precipitation forecasts for T+12, verifying at 12Z 28/09/93, in Figure 7. The trial forecast (Figure 7a) has predicted extra small patches of very light rain in the northwesterly airsteam west of 30W from cloud in levels 3-4.

Only one forecast, (T+30 forecast from DT 00Z 9/9/93) from of the forty-five assessed, was noticeably spottier over the U.K.. The trial and operational T+30 forecasts verifying at 06Z 10/09/93 are compared in Figure 8. The trial forecast, (Figure 8a), predicted additional very light rain over the Midlands in the moist southwesterly airsteam around a depression. This was a correct forecast.

Some larger patches of light dynamic rain over the sea were noticed in some October trial forecasts. An example is given by the T+24 trial forecast verifying at 00Z 12/10/93 shown in Figure 9a. The area concerned, between 55N and 60N and 10W to 20W, had a rainfall rate of 0.1 to 0.5mm/hr and 6-hour accumulation 1mm. The corresponding operational forecast, Figure 9b, predicted only light showers in this region. This area of dynamic rain in the trial forecast came from boundary layer cloud with a temperature below freezing. The trial and operational cloud charts compared in Figures 10a and 10b respectively, show that the trial forecast had 90-100% cloud at model level 5 in this region compared to only 40-50% in the operational forecast. The meteosat infrared satellite images for 23Z 11th October and 01Z 12th October (Figures 11a and 11b) showed evidence of some low cloud in this region but it didnot look particularly rain-bearing. Trial and operational model ascents for 58N 12W,verifying at T+24 are compared in Figures 12a and 12b respectively. The ascents, which are very similar, both showed a sub-freezing layer of cloud between 900mb and 800mb. Both ascents were unstable and the main difference was that the trial ascent was slightly moister.

**c) Convective rainfall**

Differences in convective rain forecasts were generally small and insignificant. Just two cases out of 45 showed differences over the U.K. (DT 00Z 11/10/93, DT00Z 09/10/93). In both of these forecasts, the trial version predicted showers to be more widespread than in the operational forecast. The first case was a poor forecast with an evolution error in the main frontal rain and so is not shown here.

In the second case, the trial forecast for T+12, verifying at 12Z 9/10/93, Figure 13a, predicted more showers over Northern England than the operational forecast(Figure 13b). The reason was that the operational forecast predicted more low cloud (see Figure 14b) and lower temperatures over Northern England. The trial and operational T+12 forecast ascents for Aughton (Figures 15 a and b respectively) were similar except in the lowest 100mb,

where the trial ascent was slightly warmer and drier. In the event, the radar image for 12Z 9/10/93, Figure 16, confirms that there were no showers over Northern England so the operational rainfall forecast was correct inspite of an incorrect cloud forecast.

**d) Temperature**

Differences between 1.5m temperatures were small but trial forecasts tended to be slightly colder at night, especially over high ground. The trial and operational 1.5m temperature forecasts for T+30, verifying at 06Z 16/10/93, are compared in Figures 17a and 17b respectively. The forecasts are very similar but extreme values are slightly lower in the trial forecast (compare trial values of -18C over Iceland, -6C over England, -2C over the continent with the corresponding operational values of -17C, -5C and -1C).

The U.K. observations for 06Z (Figure 18) show temperatures generally between -1C and -6C, whilst the minimum temperature overnight was -9C at Shap, Cumbria.

**3. Summer deep convection case, DT12Z 8/06/93.**

This was a typical breakdown of a hot,dry,humid spell of weather, with the development of widespread thunderstorms over the U.K. during 9th June. The radar composite, Figure 19, shows the location of showers and thunderstorms at 18Z 9th June. The T+30 forecast of total rainfall rate and mean sea level pressure from the trial version verifying at this time is shown in Figure 20. The model predicted widespread heavy showers over most of the U.K. but there were errors in distribution. The operational forecast, shown in Figure 21, was almost identical over the U.K.. In fact, there were very few differences in forecast rainfall anywhere in the LAM area apart from minor differences in light rain/showers near the depression south of Iceland.

**4. Winter snow case, DT00Z 24/01/93.**

January 24th was a windy day with showers affecting many parts. The south was mild at first but it gradually turned colder everywhere from the northwest during the day with the showers turning to snow in the north. Isolated hail and thunderstorms were also reported over Northern England.

The radar image for 18Z 24/01/93, Figure 22a, showed two distinct troughs over the U.K.. The northern trough over Southern Scotland was associated with snow, occasionally heavy. The southern trough over Northern England was associated with heavy showers mainly of rain but turning to snow over high ground. Showers further south over the Midlands and Southwest England were lighter and of rain.

If we compare this radar image with the T+18 precipitation forecasts from the trial and operational models (Figure 23a and 24a respectively), then both predicted the area of precipitation quite well, without getting the detail of two separate troughs.

The trough over Southern Scotland was better covered by the more widespread precipitation in the trial forecast, but the operational forecast brought snow further south correctly.

The radar image for 00Z 25/01/93, Figure 22b, showed that most showers were confined to Scotland, Northwest England and Southwest England, with sheltered eastern areas of England staying dry and clear.

There was a marked difference between the trial and operational precipitation forecasts compared in Figures 23b and 24b respectively. In comparison with the radar image, Figure 22b, the trial precipitation was too widespread losing the shelter effect over Eastern England. The operational forecast was better in this case.

Comparing the cloud forecasts for T+24 in Figure 25, shows that the trial forecast ,Figure 25a, retained too much cloud, both at medium levels and at levels 3,4 in the boundary layer.

The differences between the trial and operational forecasts in this case were due to the changes in the treatment of cloud ice, which resulted in an increase of ice cloud and light precipitation.

## 5. Objective Assessment

A one timestep forecast was run from the T+24 model forecast dumps retained from each trial and operational forecast run during September trial. The T+24 forecast fields were then verified against the relevant acobs file.

a) Temperature errors at T+24, verifying at 00Z

| | mean errors(model-obs) | | rms errors | |
|---|---|---|---|---|
| level | trial | oper | trial | oper |
| 1 | -0.87 | -0.77 | 2.36 | 2.33 |
| 2 | 0.20 | 0.27 | 1.81 | 1.80 |
| 3 | 0.22 | 0.30 | 1.75 | 1.73 |
| 4 | 0.03 | 0.08 | 1.49 | 1.49 |
| 5 | -0.17 | -0.15 | 1.41 | 1.41 |
| 6 | 0.04 | 0.05 | 1.31 | 1.28 |
| 7 | -0.02 | -0.02 | 1.27 | 1.23 |
| 8 | -0.12 | -0.13 | 1.29 | 1.25 |
| 9 | -0.27 | -0.28 | 1.28 | 1.27 |
| 10 | -0.47 | -0.48 | 1.39 | 1.37 |
| 11 | -0.58 | -0.57 | 1.57 | 1.55 |
| 12 | -0.43 | -0.38 | 1.78 | 1.74 |

TABLE 1. Mean and rms temperature errors at T+24 verified against acobs for model levels 1-12 and meaned over the period 9-30th September 1993.

The cold bias at level 1 increased slightly in the trial forecasts from -0.77 to -0.87, confirming the subjective assessment of lower minimum temperatures. The warm bias in levels 2,3 and 4 were slightly reduced in the trial forecasts. Verification for levels 5-11 were very similar in both versions

but the cold bias at level 12 (~250mb) was slightly larger.

The rms scores were very close, marginally favouring the operational forecasts but only in the second decimal place.

b) pstar

| mean error(model-obs) | | rms error | |
|---|---|---|---|
| trial | oper | trial | oper |
| -0.554 | -0.572 | 1.86 | 1.88 |

TABLE 2. Mean and rms errors for pstar at T+24 verified against acobs and meaned over the period 9-30th September 1993.

The verification for pstar marginally favoured the trial forecasts.

c) Wind speed rms errors

| level | oper | trial |
|---|---|---|
| 1 | 4.86 | 4.88 |
| 2 | 5.76 | 5.77 |
| 3 | 5.33 | 5.34 |
| 4 | 4.69 | 4.69 |
| 5 | 4.60 | 4.60 |
| 6 | 4.46 | 4.47 |
| 7 | 4.51 | 4.52 |
| 8 | 5.01 | 5.03 |
| 9 | 5.82 | 5.84 |
| 10 | 6.88 | 6.90 |
| 11 | 7.89 | 7.91 |
| 12 | 7.72 | 7.73 |

TABLE 3. Windspeed rms errors at T+24 verified against acobs and meaned over the period 9-30th September 1993.

The wind scores show that the changes had no impact upon the windspeed.

## 6. CONCLUSIONS

1. No changes in forecast evolution and most differences were trivial.

2. Calling the convection every other timestep had very little impact upon convective rainfall forecasts. There were no forecast failures in 3 months. Time saving was up to 10%.

3. Slight increase of light precipitation over the sea.
(i) more light showers south of 40N
(ii) slightly spottier over the sea
(iii) a few small areas of light dynamic rain were predicted in some early October cases. The light rain fell from boundary layer cloud with temperatures below freezing.

4. Minimum temperatures slightly lower.

5. There was a small increase in ice cloud generally. In winter cases with cloud temperatures below freezing, this can lead to an increase in boundary layer cloud and light precipitation. More specifically, an increase in level 1 cloud in wintry precipitation.

**FIGURES**

| | |
|---|---|
| Figure 1 | T+36 forecast for mean sea level pressure and total precipitation rate verifying at 12Z 11/10/93. |
| Figure 2a | T+36 forecast of level 1 cloud (>70% shaded) from the trial forecast verifying at 12Z 11/10/93. |
| Figure 2b | As Figure 2a but for the operational model. |
| Figure 3a | T+12 forecast of low and medium cloud amounts output shows amounts >4octas) from the trial model verifying at 12Z 11/09/93. |
| Figure 3b | As Figure 3a but for the operational model. |
| Figure 4a | T+12 forecast of level 2 cloud (>70% shaded)from the trial version verifying at 12Z 11/09/93. |
| Figure 4b | As Figure 4a but for the operational model. |
| Figure 5a | T+12 forecast tephigram for Boulmer from the trial model verifying at 12Z 11/09/93. |
| Figure 5b | As Figure 5a but for the operational model. |
| Figure 6a | Observations for the British Isles for 12Z 11/09/93. |
| Figure 6b | Radiosonde ascent for Boulmer for 11Z 11/09/93. |
| Figure 7a | T+12 forecast of total precipitation rate and mean sea level pressure from the trial model verifying at 12Z 28/09/93. |
| Figure 7b | As Figure 7a but for the operational model. |
| Figure 8a | T+30 forecast of total precipitation rate and mean sea level pressure from the trial model verifying at 06Z 10/09/93. |
| Figure 8b | As Figure 8a but for the operational model. |
| Figure 9a | T+24 total precipitation rate and mean sea level forecast from the trial model, verifying at 00Z 12/10/93. |
| Figure 9b | As Figure 9a but for the operational model. |
| Figure 10a | T+24 forecast of level 5 cloud from the trial model, verifying at 00Z 12/10/93. |
| Figure 10b | As Figure 10a but for the operational model. |
| Figure 11a | Meteosat infrared satellite image for 23Z 11/10/93. |
| Figure 11b | As Figure 11a but for 01Z 12/10/93. |
| Figure 12a | T+24 forecast tephigram for 58N 12W from the trial model verifying at 00Z 12/10/93. |
| Figure 12b | As Figure 12a but from the operational model. |

| | |
|---|---|
| Figure 13a | T+12 forecast of total precipitation rate and mean sea level pressure from the trial model, verifying 12Z 09/10/93. |
| Figure 13b | As Figure 13a but from the operational model. |
| Figure 14a | T+12 forecast of low and medium cloud (output gives amounts >4 octas) from the trial model, verifying at 12Z 09/10/93. |
| Figure 14b | As Figure 14a but from the operational model. |
| Figure 15a | T+12 forecast ascent for Aughton, verifying at 12Z 9/10/93, from the trial model. |
| Figure 15b | As Figure 15a but for the operational model. |
| Figure 16 | Radar composite for 12Z 09/10/93 |
| Figure 17a | T+30 forecast of 1.5m temperatures from the trial model. |
| Figure 17b | As Figure 17a but from the operational model. |
| Figure 18 | U.K. observations at 06Z 16/10/93 and overnight minimum temperatures. |
| Figure 19 | Radar composite for 18Z 9th June 1993. |
| Figure 20 | Trial T+30 forecast of total rainfall rate and mean sea level pressure verifying at 18Z 9/06/93. |
| Figure 21 | Operational T+30 forecast of total rainfall rate and mean sea level pressure verifying at 18Z 9/06/93. |
| Figure 22a | Radar composite for 18Z 24/01/93 |
| Figure 22b | Radar composite for 00Z 25/01/93 |
| Figure 23 | Trial T+18/24 forecasts of mean sea level pressure and total precipitation rate, verifying at 18Z 24/01/93 and 00Z 25/01/93 respectively. |
| Figure 24 | Operational T+18/24 forecasts of mean sea level pressure and total precipitation rate, verifying at 18Z 24/01/93 and 00Z 25/01/93 respectively. |
| Figure 25a | T+24 forecast of low and medium cloud from the trial model, verifying at 00Z 25/01/93. Output shows > 4 octas. |
| Figure 25b | As Figure 25a but for the operational forecast. |

**Figure 1** **T+36 forecast for mean sea level pressure and total precipitation rate verifying at 12Z 11/10/93.**

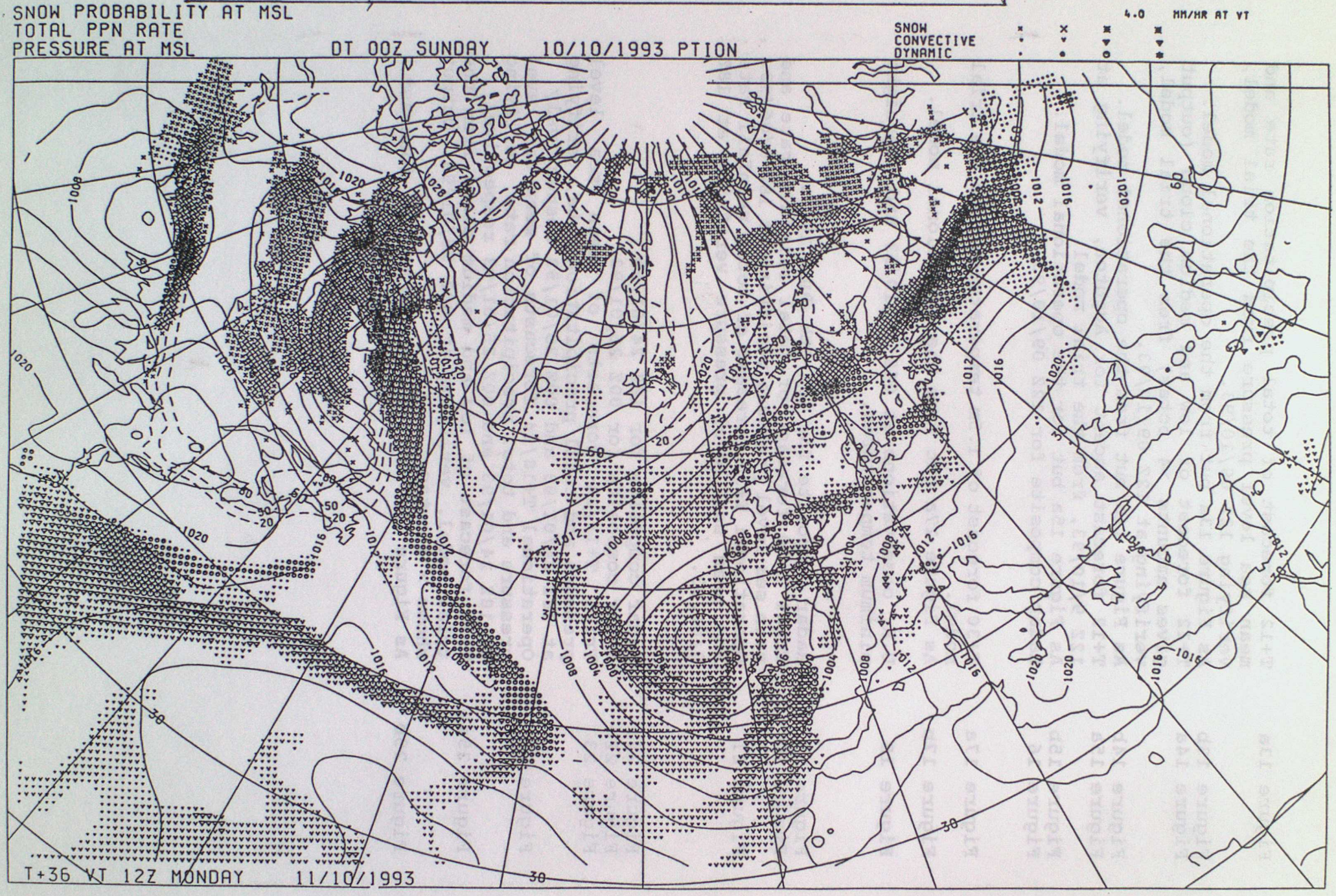


**Figure 2a** T+36 forecast of level 1 cloud (>70% shaded) from the trial forecast verifying at 12Z 11/10/93.

**Figure 2b** As Figure 2a but for the operational model.

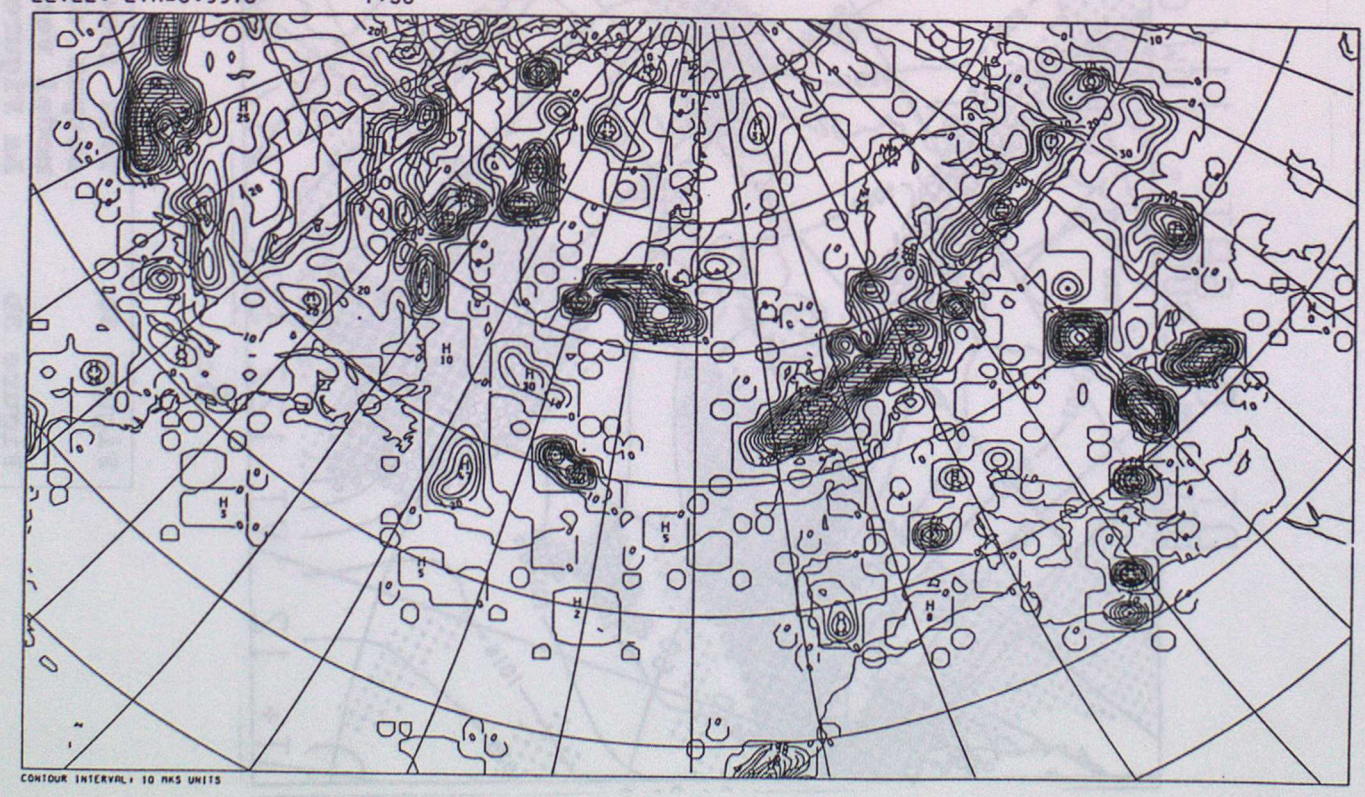
LIMITED AREA MODEL RUNID .CWSBU3Y.DPPO
CLOUD AMOUNT
VALID AT 12Z ON 11/10/1993 DAY 284 DATA TIME 0Z ON 10/10/1993 DAY 283
LEVEL: ETA=0.9970 T+36

2a

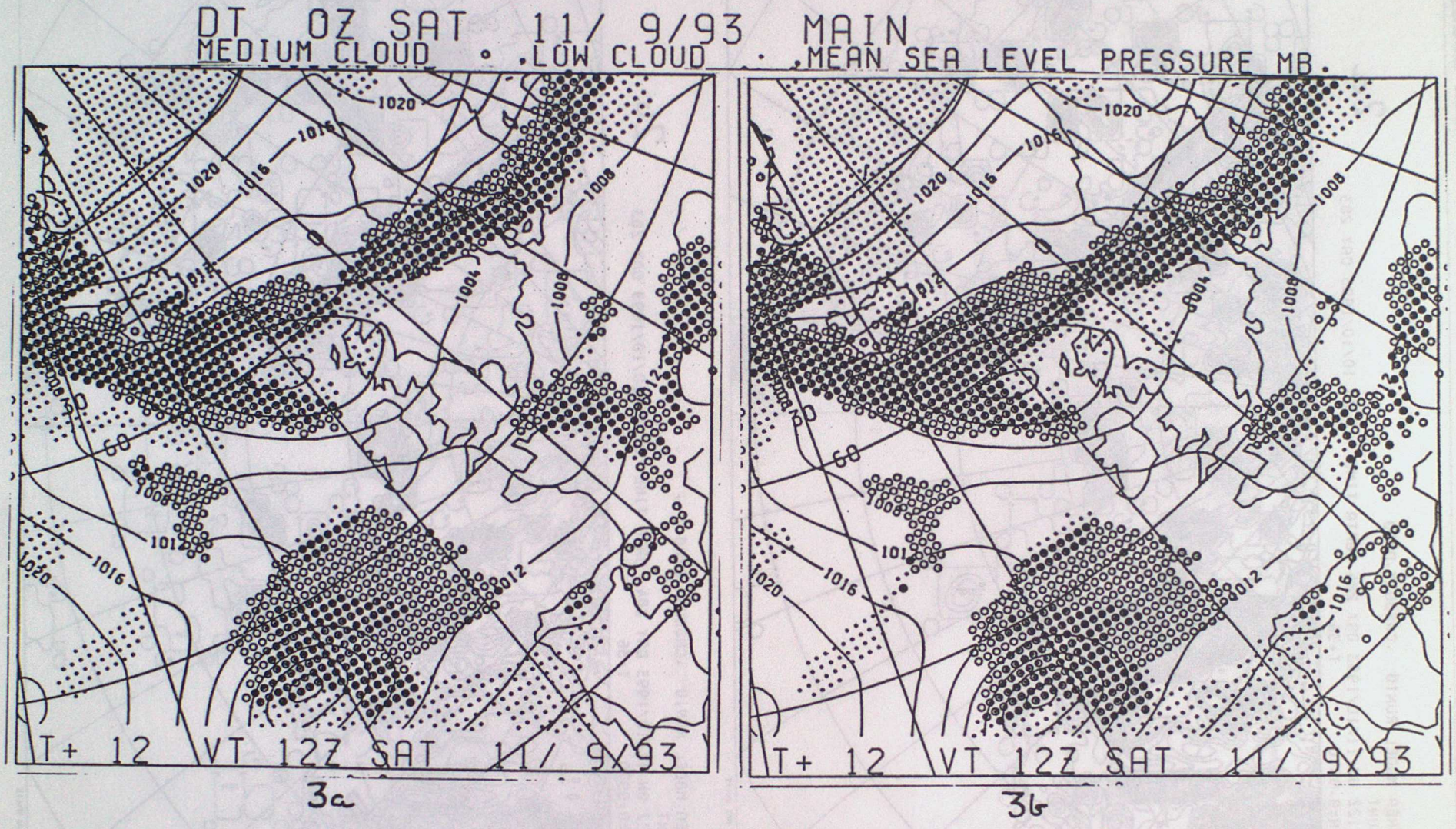
CONTOUR INTERVAL: 10 MKS UNITS

LIMITED AREA MODEL RUNID .CWSBU3X.DPPO
CLOUD AMOUNT
VALID AT 12Z ON 11/10/1993 DAY 284 DATA TIME 0Z ON 10/10/1993 DAY 283
LEVEL: ETA=0.9970 T+36

2b



CONTOUR INTERVAL: 10 MKS UNITS



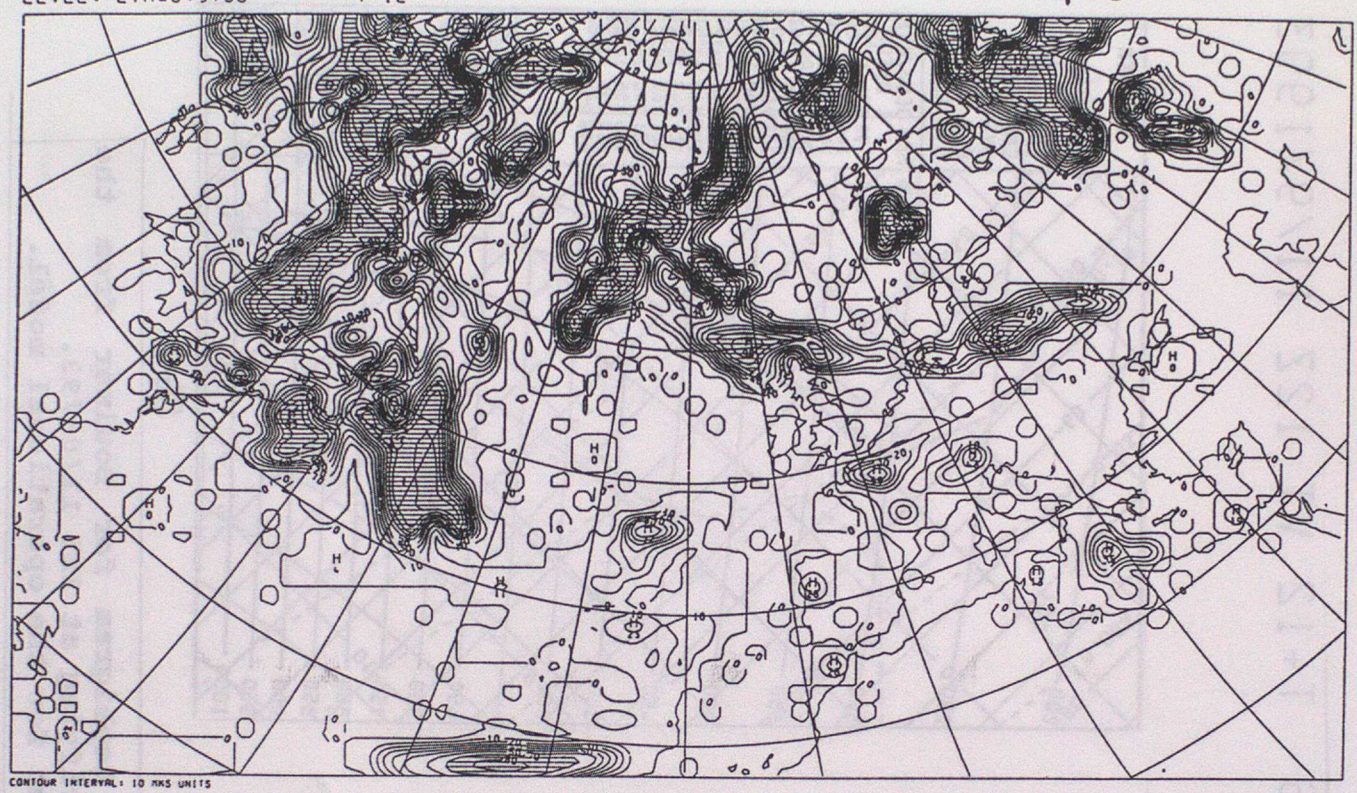

| | |
|---|---|
| **Figure 3a** | **T+12 forecast of low and medium cloud amounts output shows amounts >4octas) from the trial model verifying at 12Z 11/09/93.** |
| **Figure 3b** | **As Figure 3a but for the operational model.** |

**Figure 4a** T+12 forecast of level 2 cloud (>70% shaded) from the trial version verifying at 12Z 11/09/93.

**Figure 4b** As Figure 4a but for the operational model.

LIMITED AREA MODEL RUNID .CWSBU3Y.DPPO
CLOUD AMOUNT
VALID AT 12Z ON 11/ 9/1993 DAY 254 DATA TIME 0Z ON 11/ 9/1993 DAY 254
LEVEL: ETA=0.9750 T+12

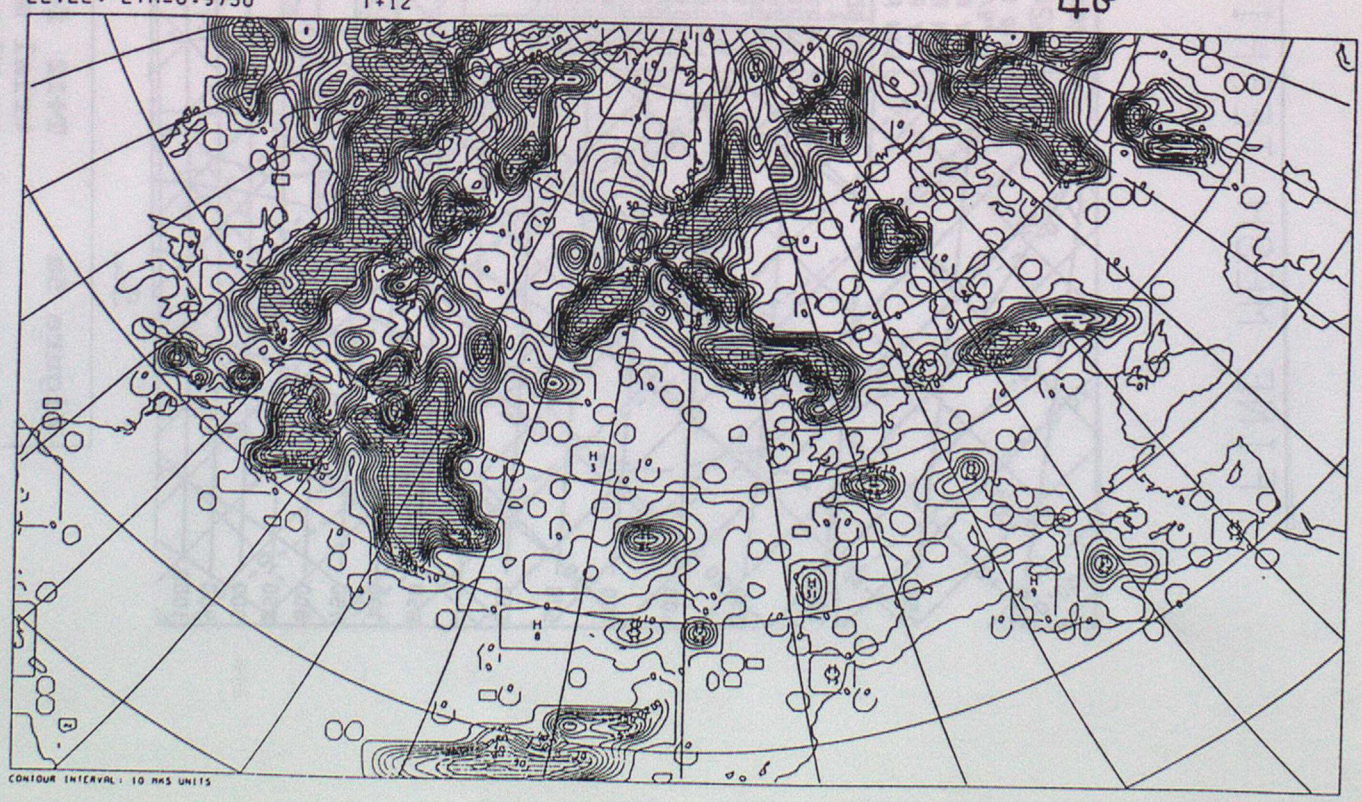
4a



CONTOUR INTERVAL: 10 MKS UNITS

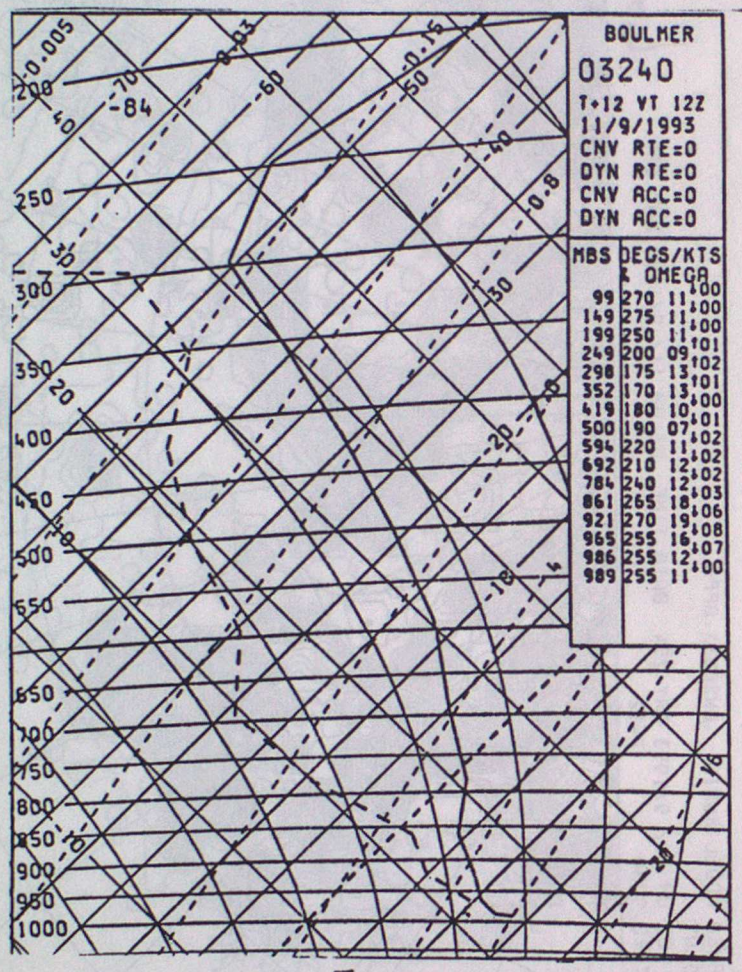
LIMITED AREA MODEL RUNID .CWSBU3X.DPPO
CLOUD AMOUNT
VALID AT 12Z ON 11/ 9/1993 DAY 254 DATA TIME 0Z ON 11/ 9/1993 DAY 254
LEVEL: ETA=0.9750 T+12

4b

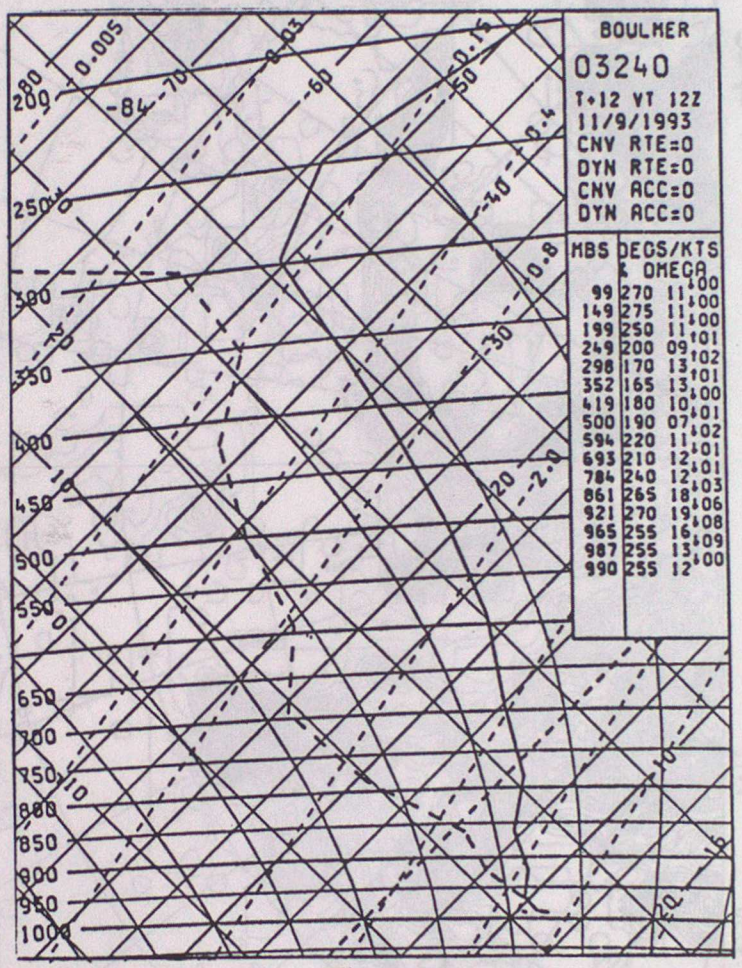


CONTOUR INTERVAL: 10 MKS UNITS

# FINE MESH TEPHIGRAMS T+12 VT 12Z 11/9/1993




5a




5b

| | |
|---|---|
| **Figure 5a** | **T+12 forecast tephigram for Boulmer from the trial model verifying at 12Z 11/09/93.** |
| **Figure 5b** | **As Figure 5a but for the operational model.** |

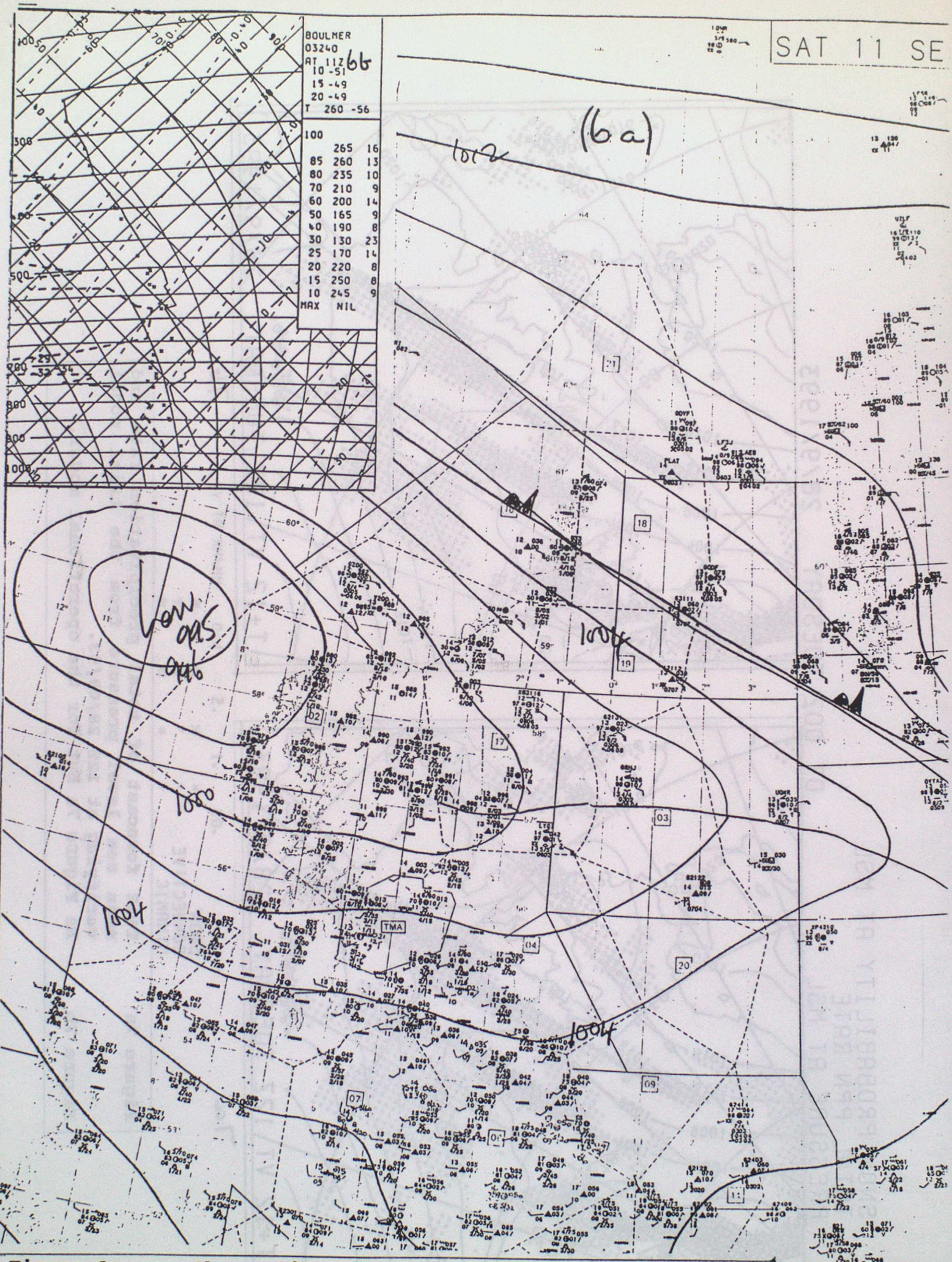



**Figure 6a** Observations for the British Isles for 12Z 11/09/93.

**Figure 6b** Radiosonde ascent for Boulmer for 11Z 11/09/93.

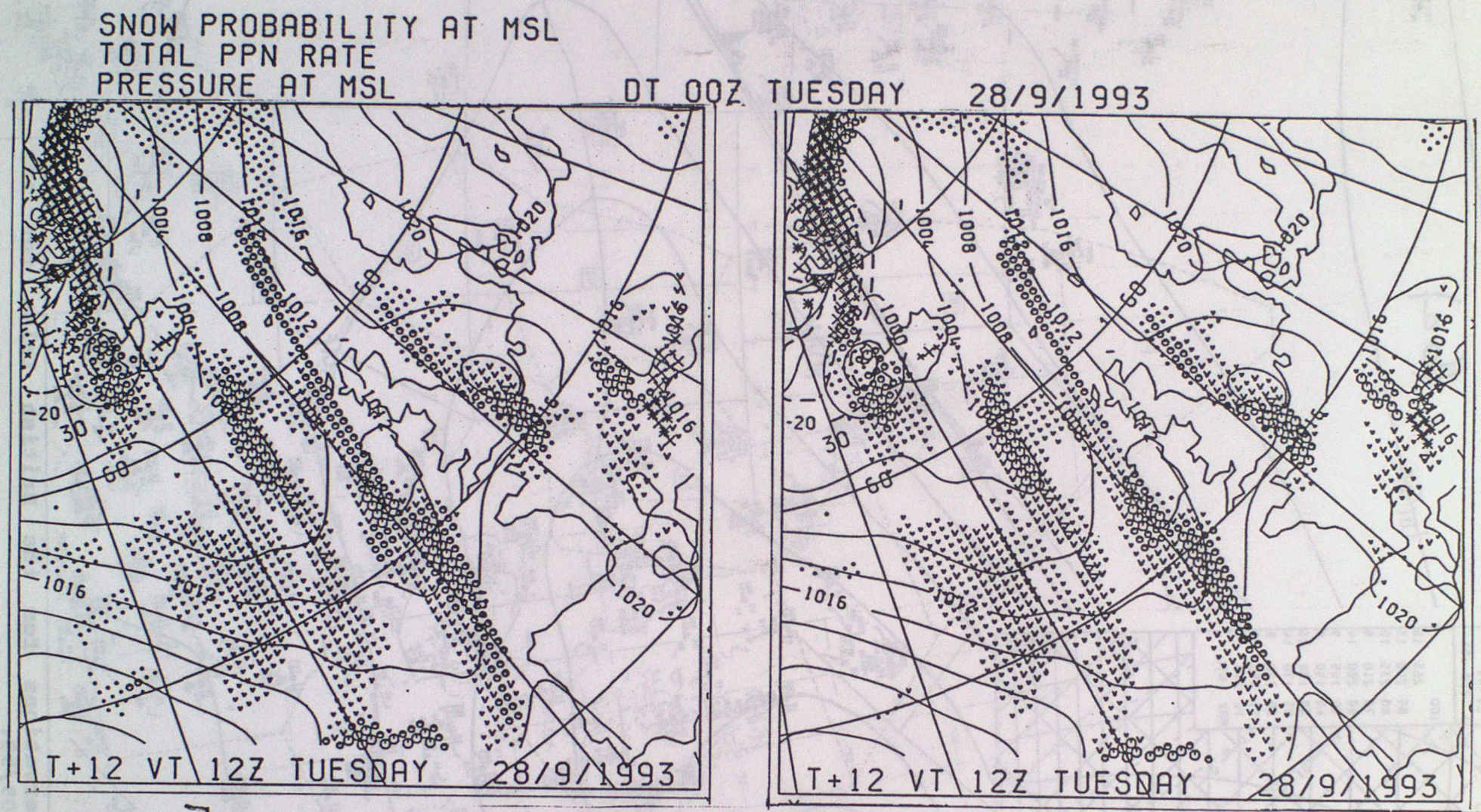



**Figure 7a** T+12 forecast of total precipitation rate and mean sea level pressure from the trial model verifying at 12Z 28/09/93.

**Figure 7b** As Figure 7a but for the operational model.

**Figure 8a** T+30 forecast of total precipitation rate and mean sea level pressure from the trial model verifying at 06Z 10/09/93.

**Figure 8b** As Figure 8a but for the operational model.

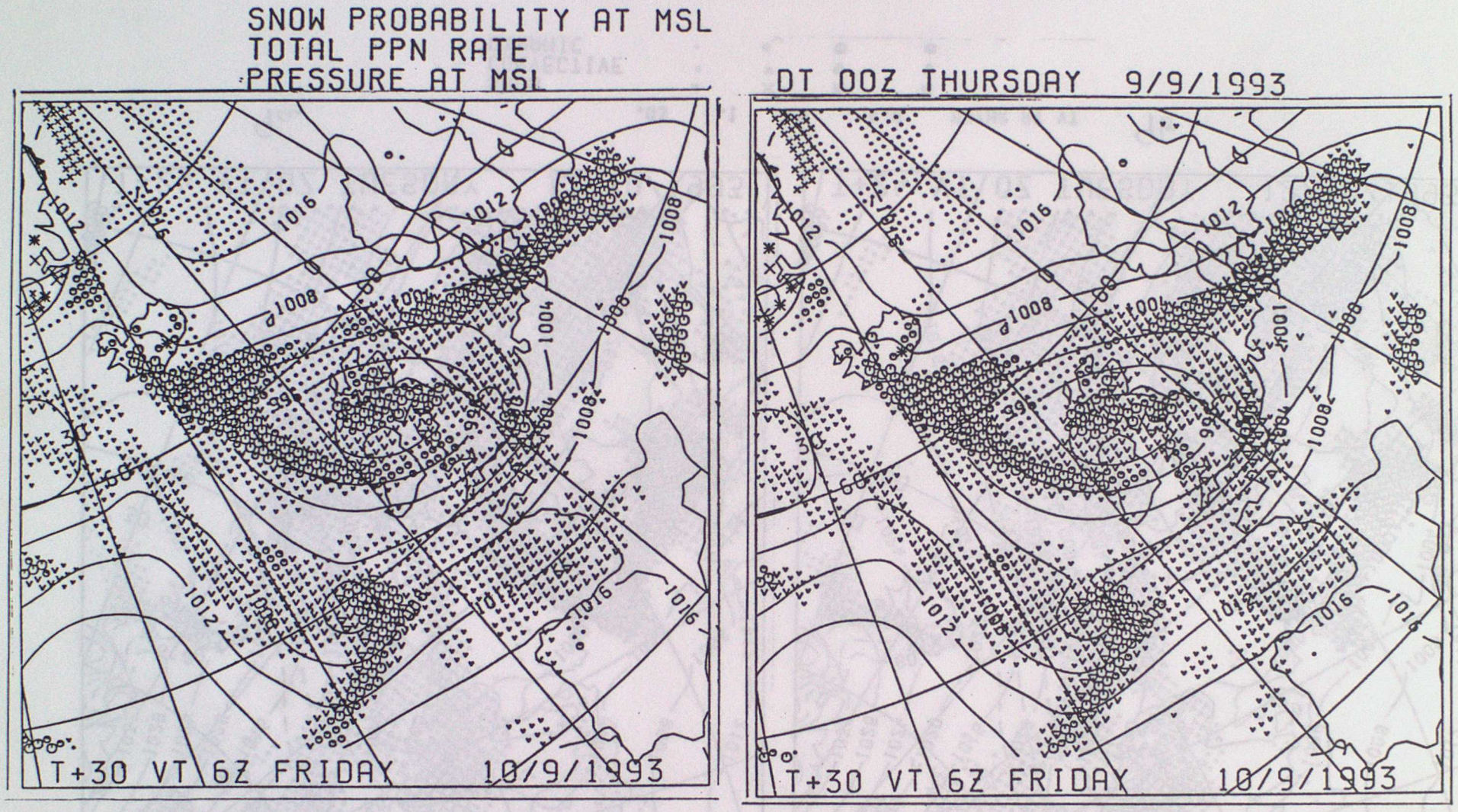


**Figure 9a** T+24 total precipitation rate and mean sea level forecast from the trial model, verifying at 00Z 12/10/93.

**Figure 9b** As Figure 9a but for the operational model.

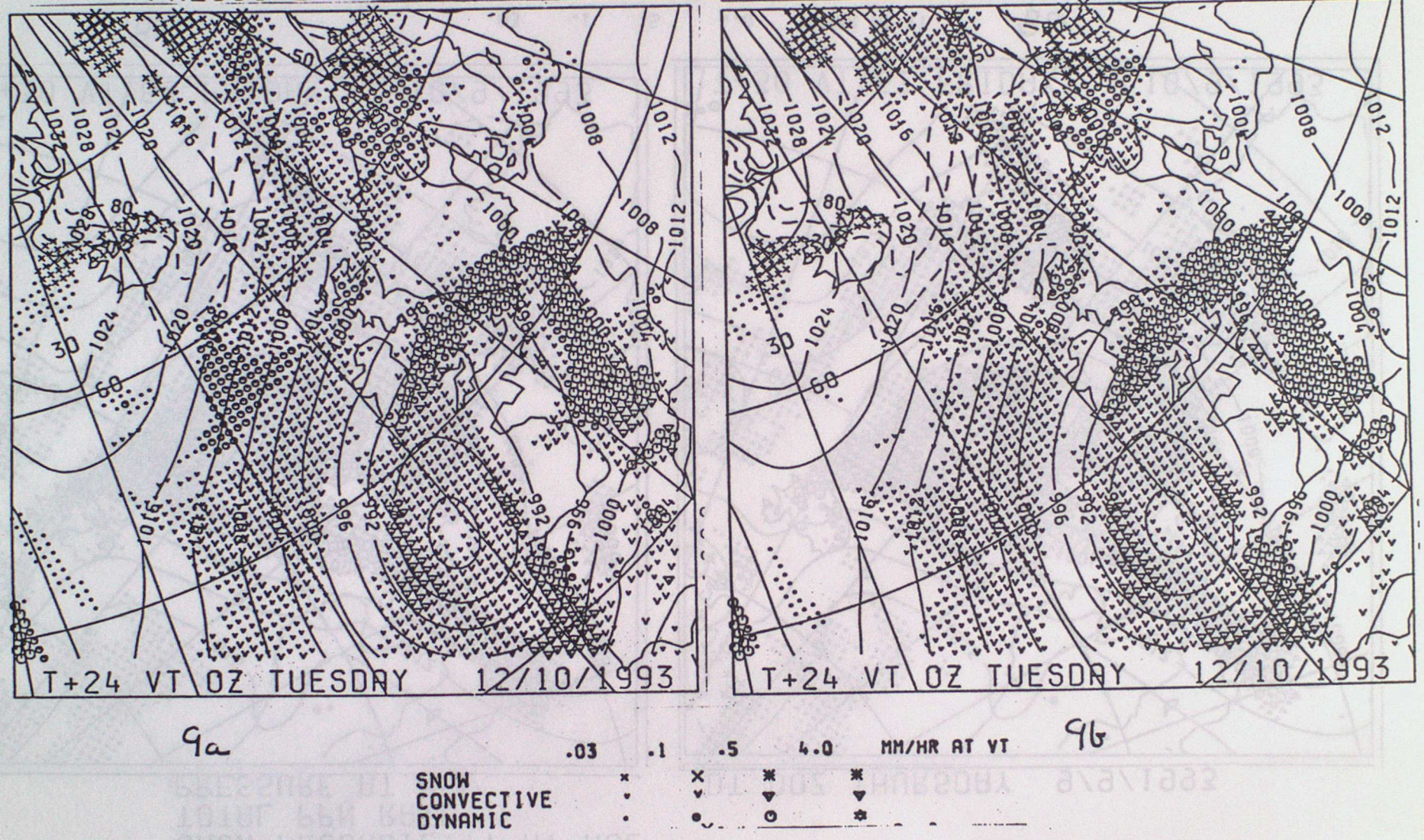
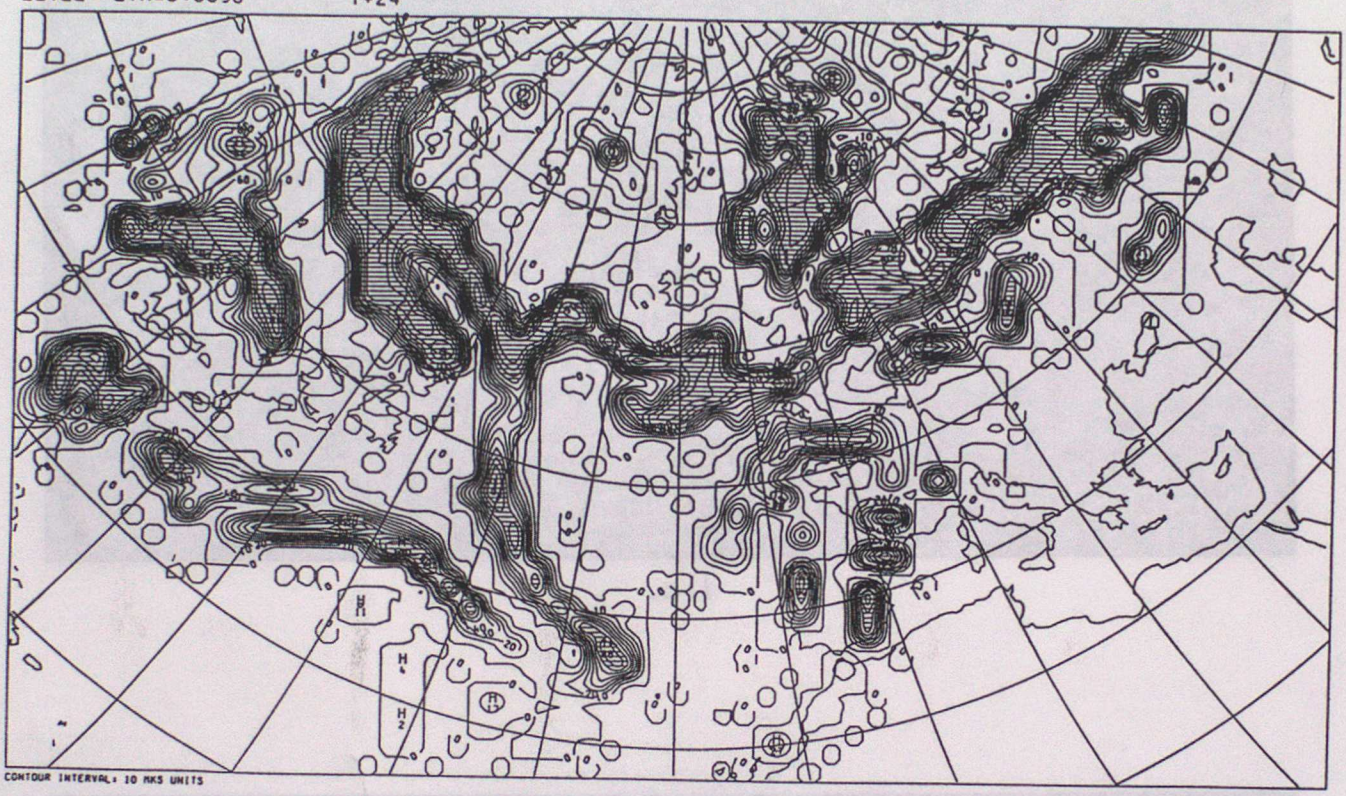


**Figure 10a** T+24 forecast of level 5 cloud from the trial model, verifying at 00Z 12/10/93.

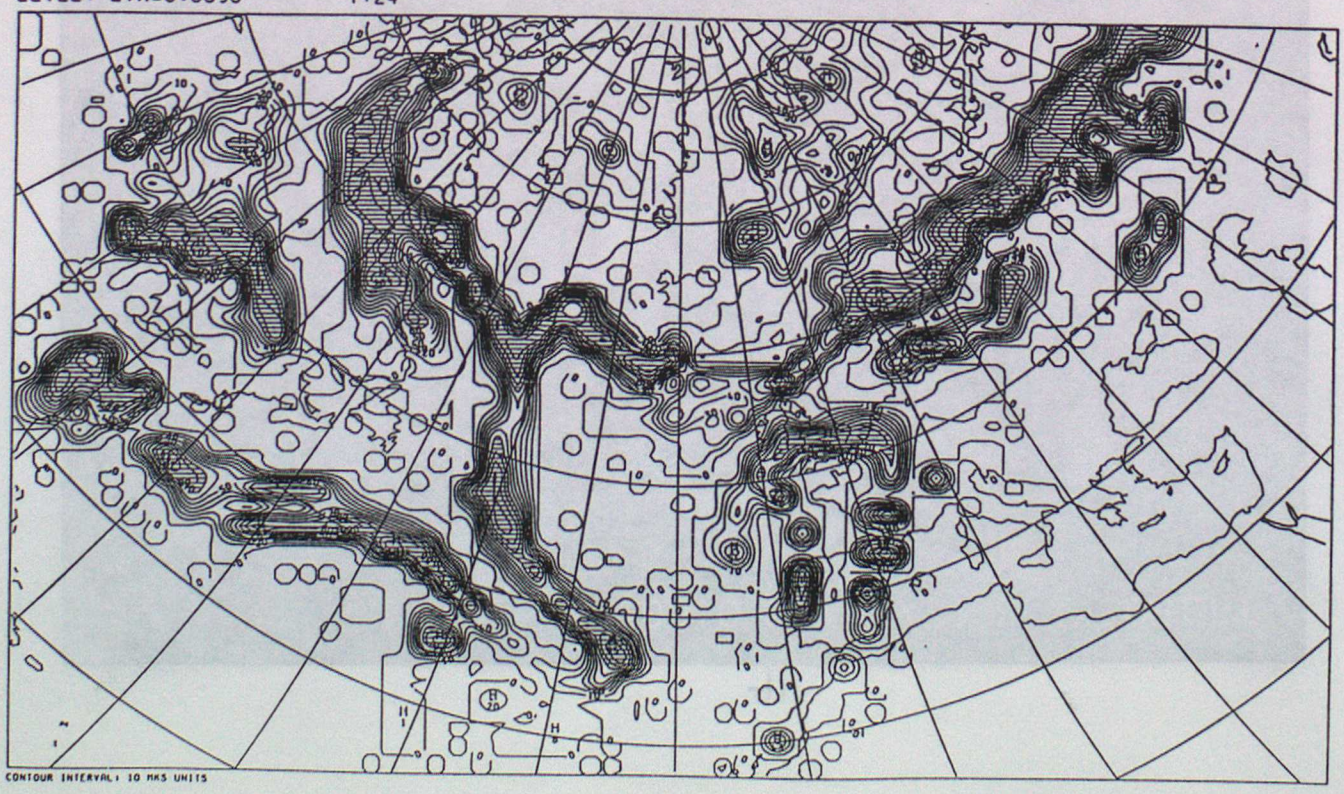
**Figure 10b** As Figure 10a but for the operational model.

LIMITED AREA MODEL RUNID .CWSBU3Y.DPPO
CLOUD AMOUNT
VALID AT 0Z ON 12/10/1993 DAY 285 DATA TIME 0Z ON 11/10/1993 DAY 284 10a
LEVEL: ETA=0.8698 T+24



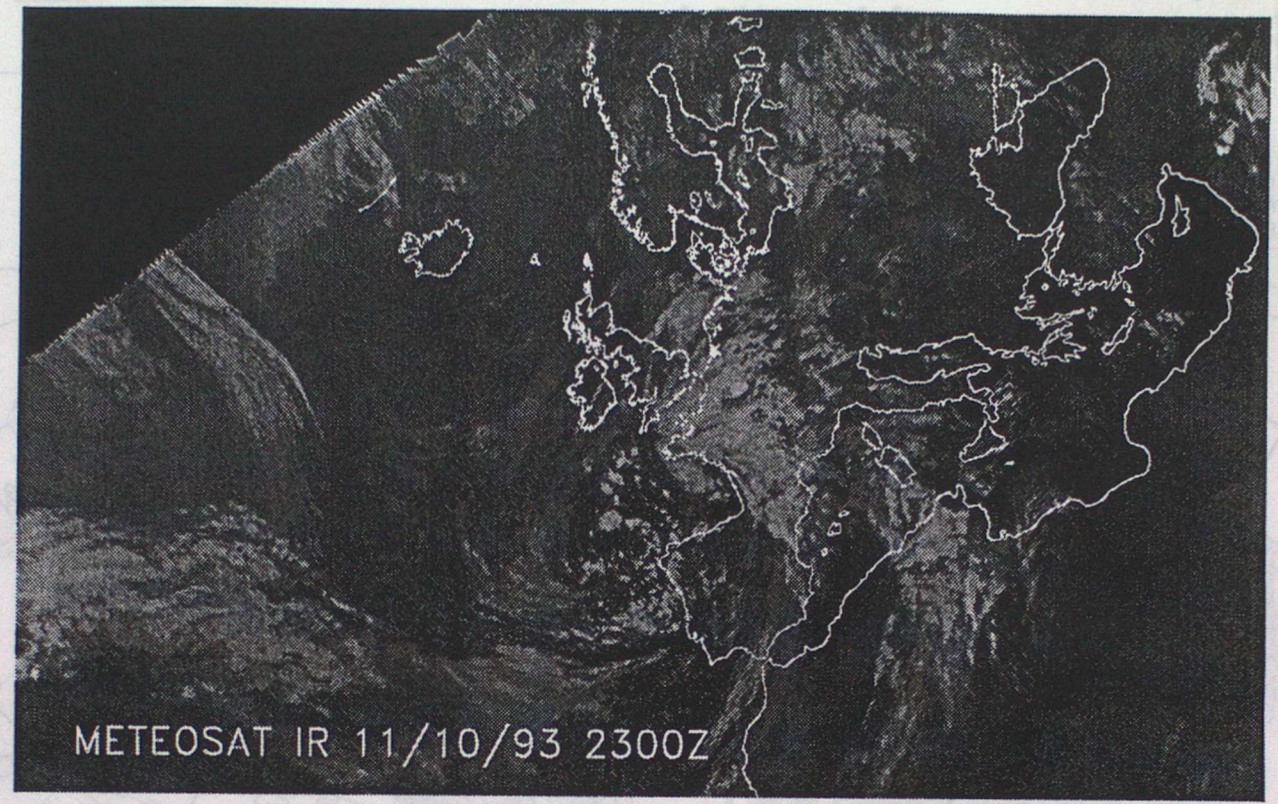
CONTOUR INTERVAL: 10 MKS UNITS

LIMITED AREA MODEL RUNID .CWSBU3X.DPPO
CLOUD AMOUNT
VALID AT 0Z ON 12/10/1993 DAY 285 DATA TIME 0Z ON 11/10/1993 DAY 284 10b
LEVEL: ETA=0.8698 T+24

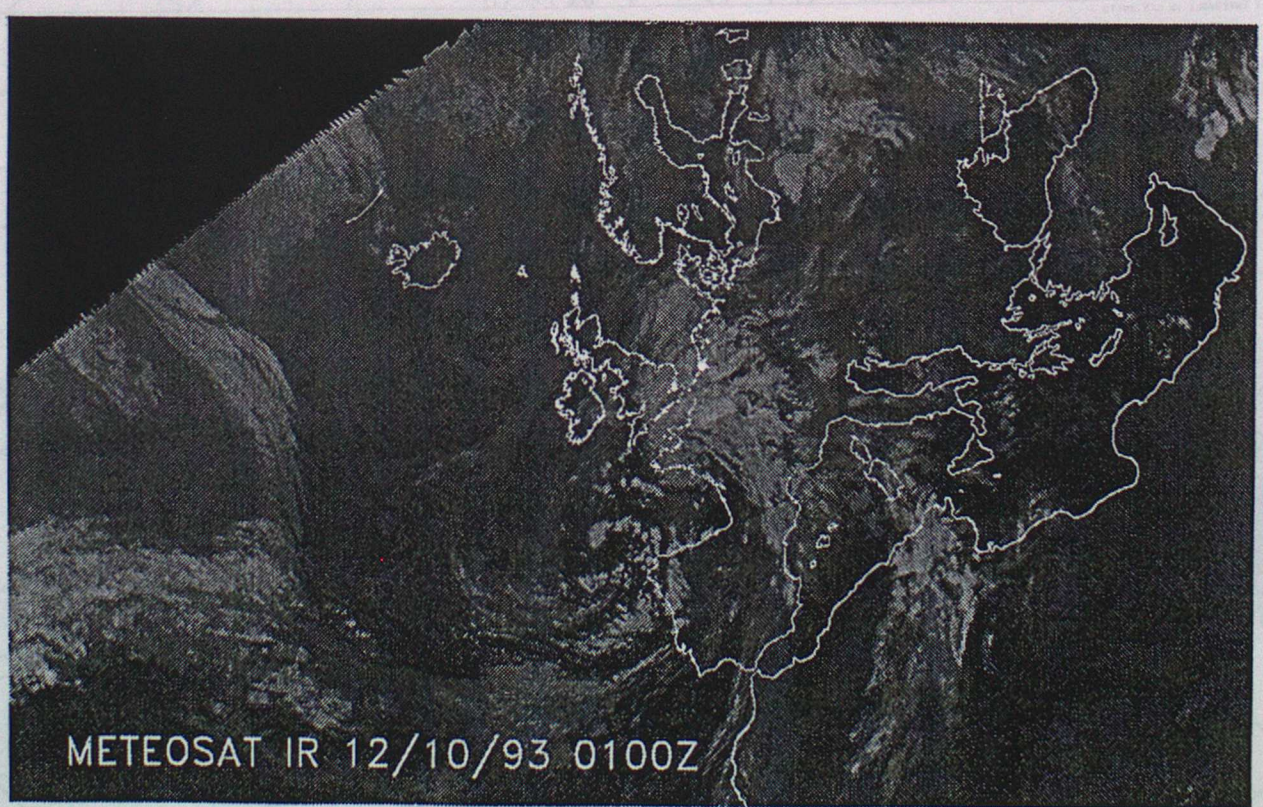


CONTOUR INTERVAL: 10 MKS UNITS

| | |
|---|---|
| Figure 11a | Meteosat infrared satellite image for 23Z 11/10/93. |
| Figure 11b | As Figure 11a but for 01Z 12/10.93. |

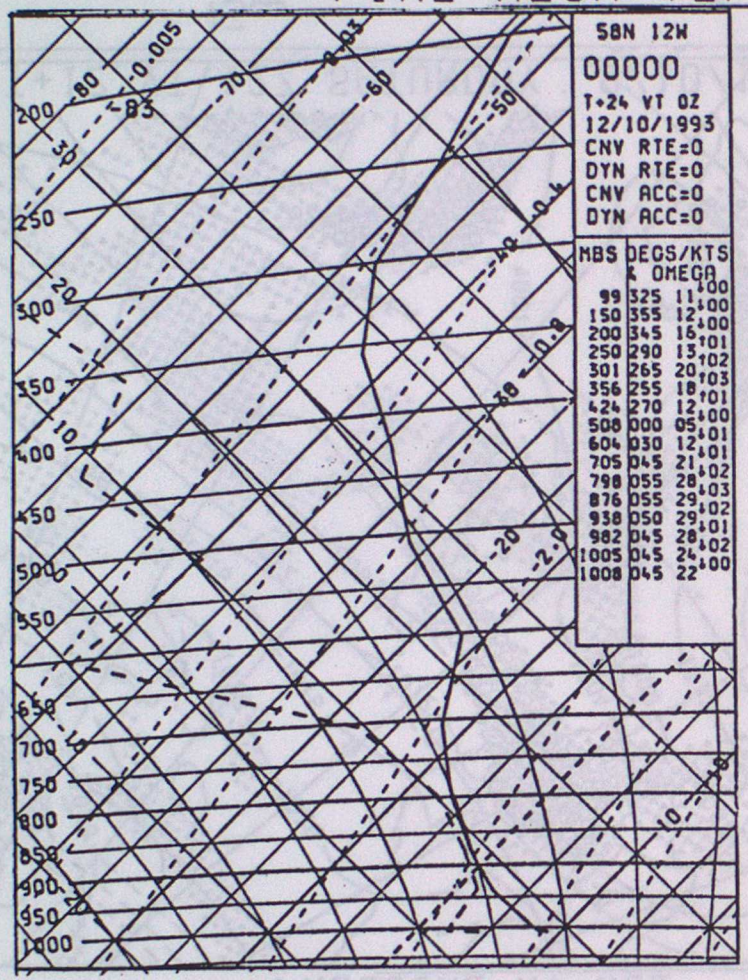



11a

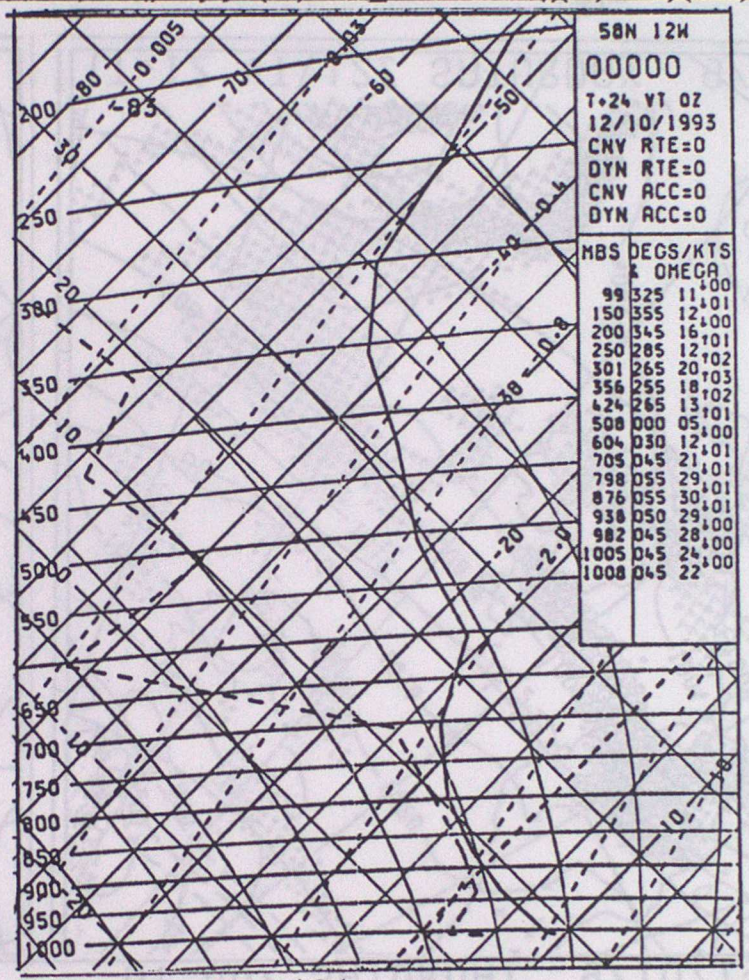



11b

# FINE MESH TEPHIGRAMS T+24 VT 0Z 12/10/1993




12a



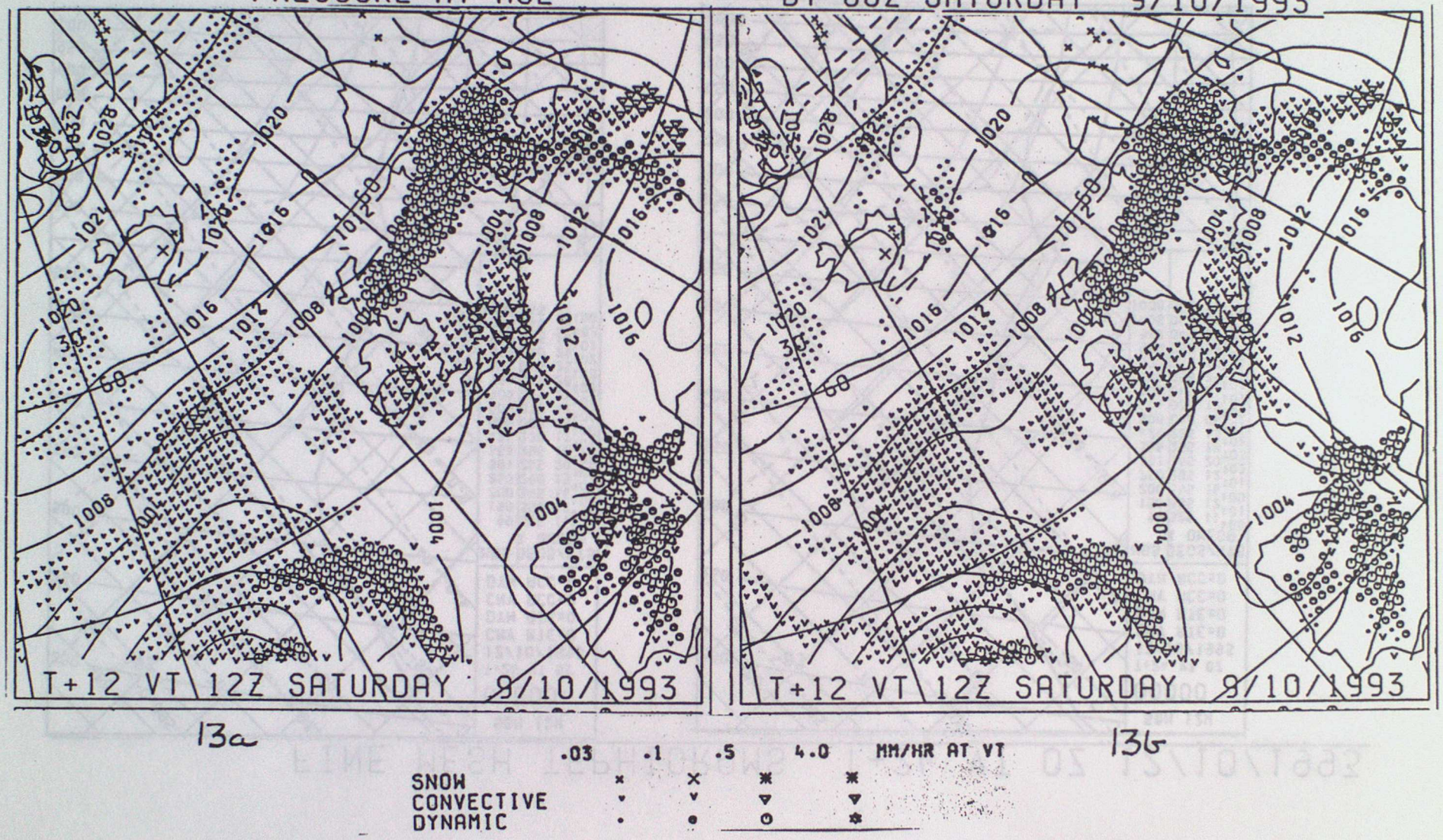

12b

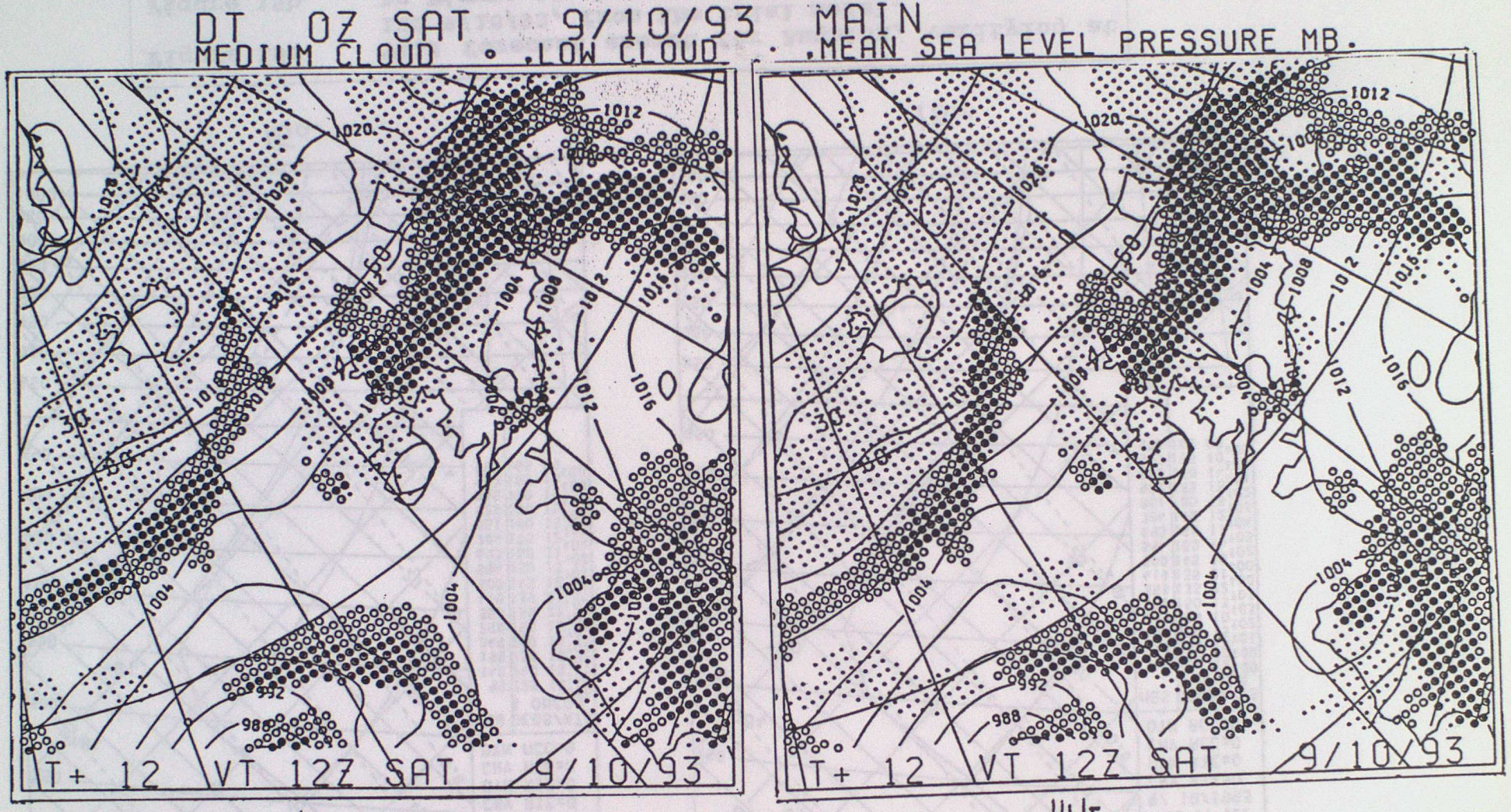
**Figure 12a** T+24 forecast tephigram for 58N 12W from the trial model verifying at 00Z 12/10/93.

**Figure 12b** As Figure 12a but from the operational model.

**Figure 13a** T+12 forecast of total precipitation rate and mean sea level pressure from the trial model, verifying 12Z 09/10/93.

**Figure 13b** As Figure 13a but from the operational model.



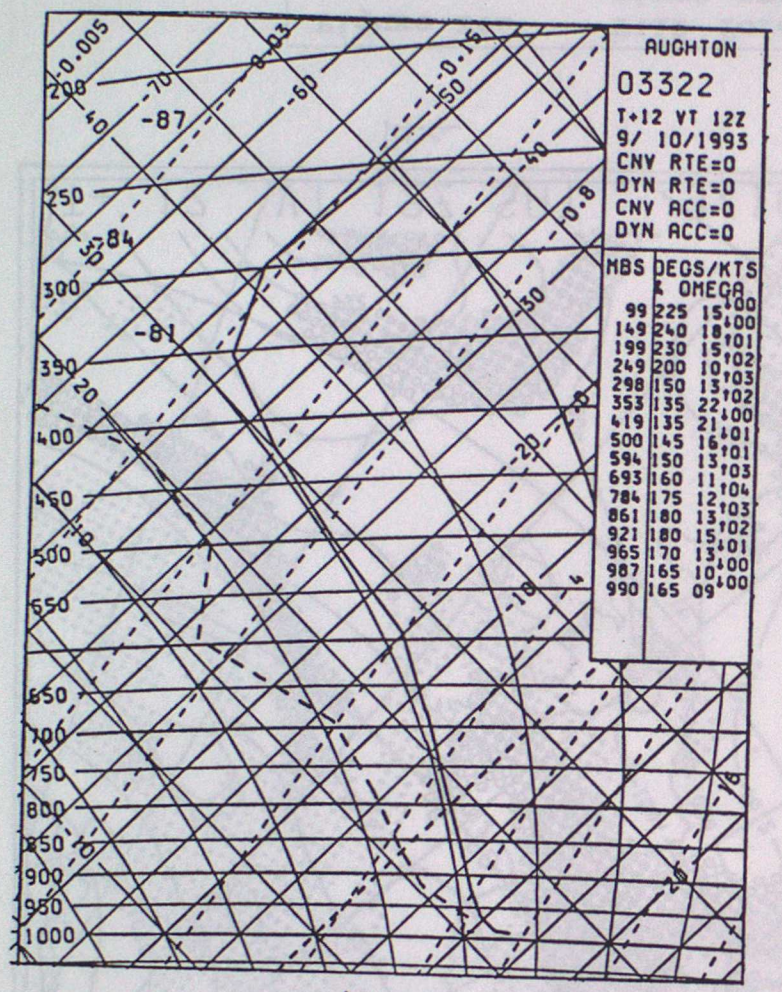



14a

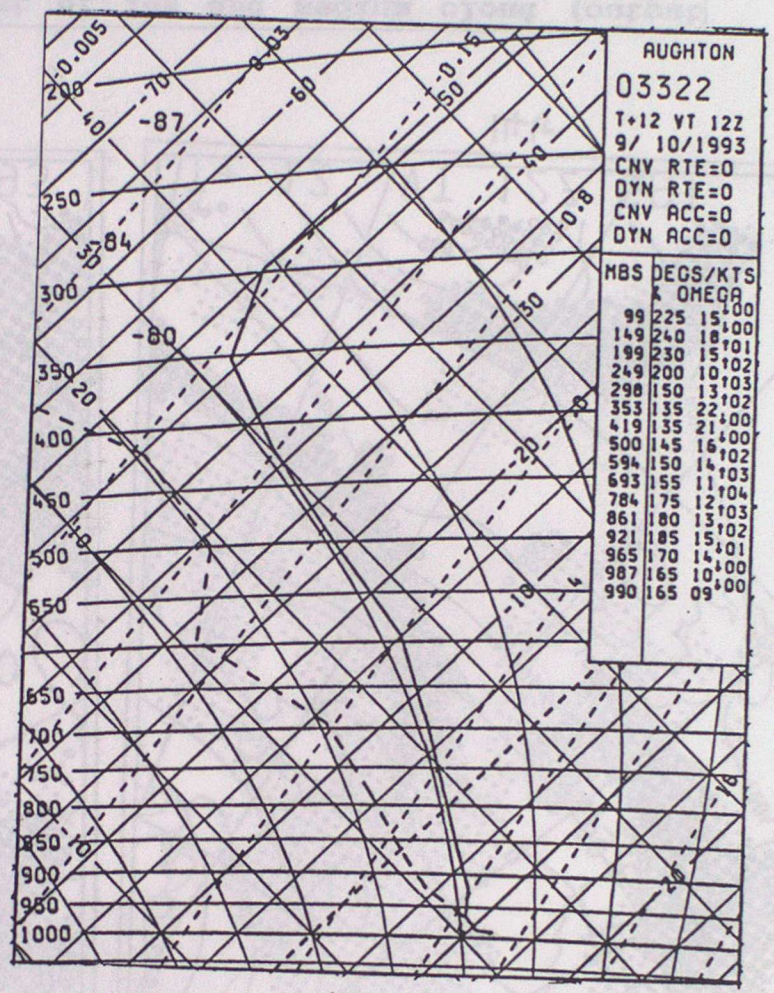
14b

| | |
|---|---|
| **Figure 14a** | **T+12 forecast of low and medium cloud (output gives amounts >4 octas) from the trial model, verifying at 12Z 09/10/93.** |
| **Figure 14b** | **As Figure 14a but from the operational model.** |

# FINE MESH TEPHIGRAMS T+12 VT 12Z 9/10/1993




15a

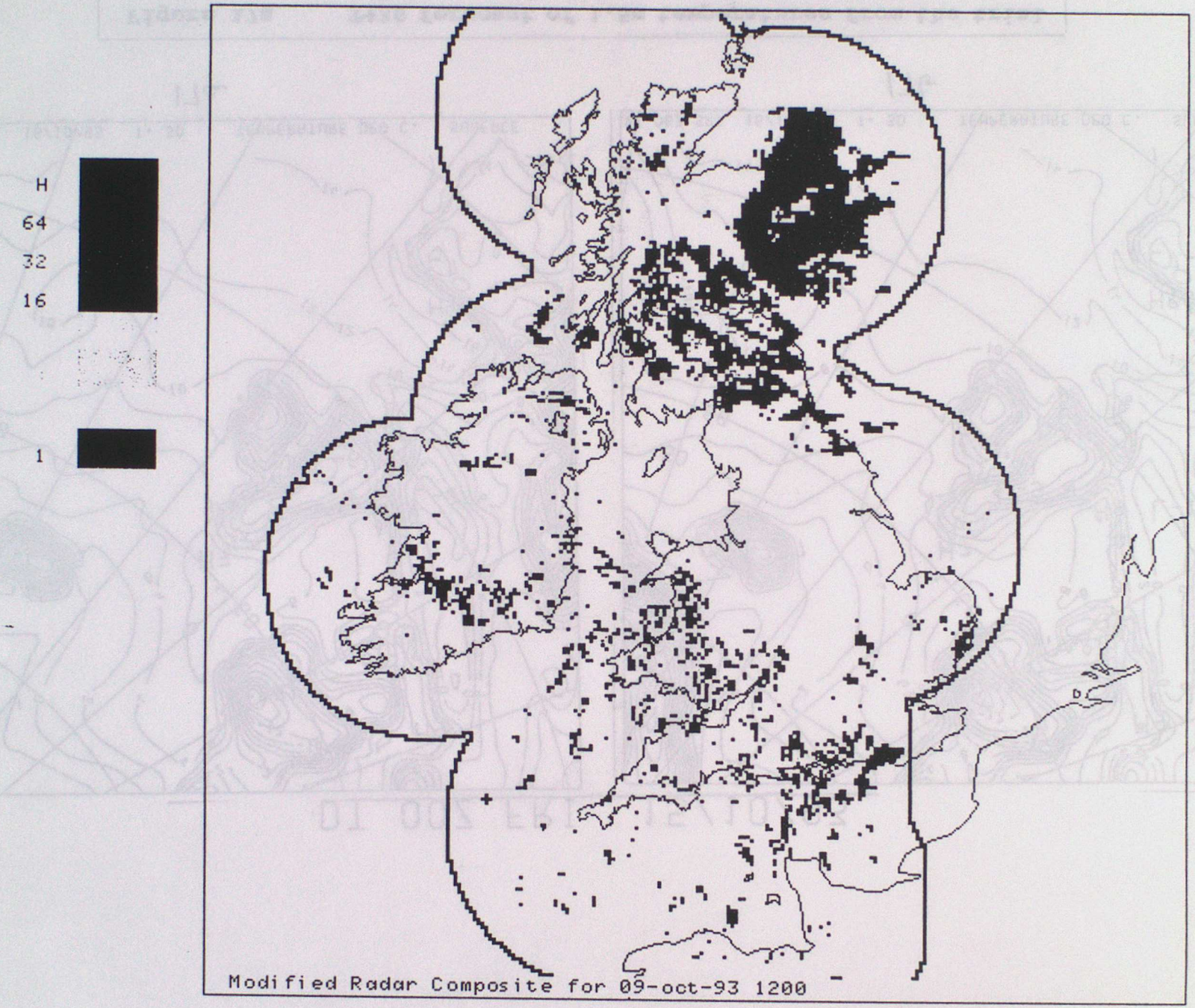


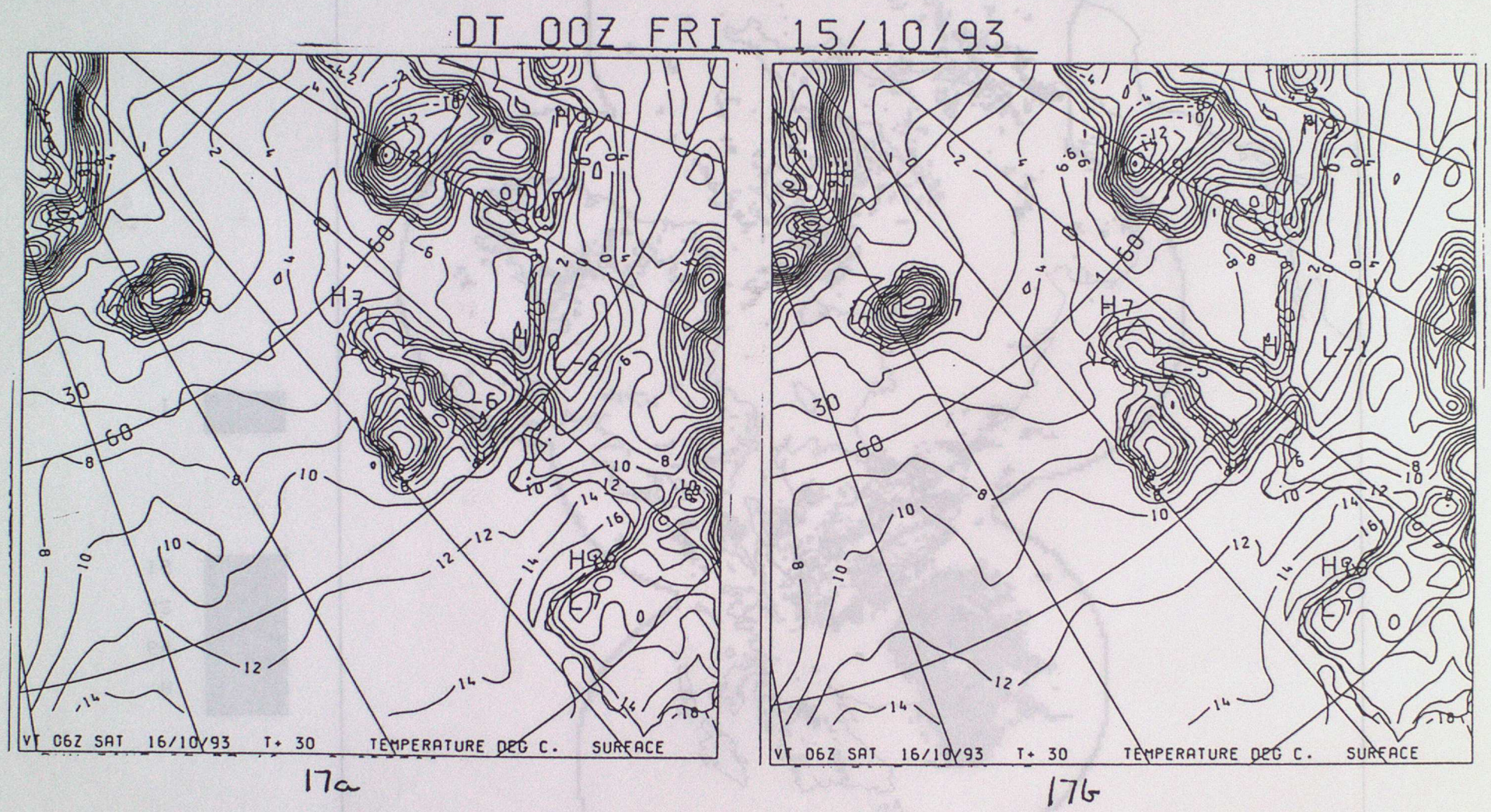

15b

**Figure 15a** T+12 forecast ascent for Aughton, verifying at 12Z 9/10/93, from the trial model.

**Figure 15b** As Figure 15a but for the operational model.

**Figure 16 Radar composite for 12Z 09/10/93**






| | |
|---|---|
| **Figure 17a** | **T+30 forecast of 1.5m temperatures from the trial model.** |
| **Figure 17b** | **As Figure 17a but from the operational model.** |

**Figure 18** **U.K. observations at 06Z 16/10/93 and overnight minimum temperatures.**

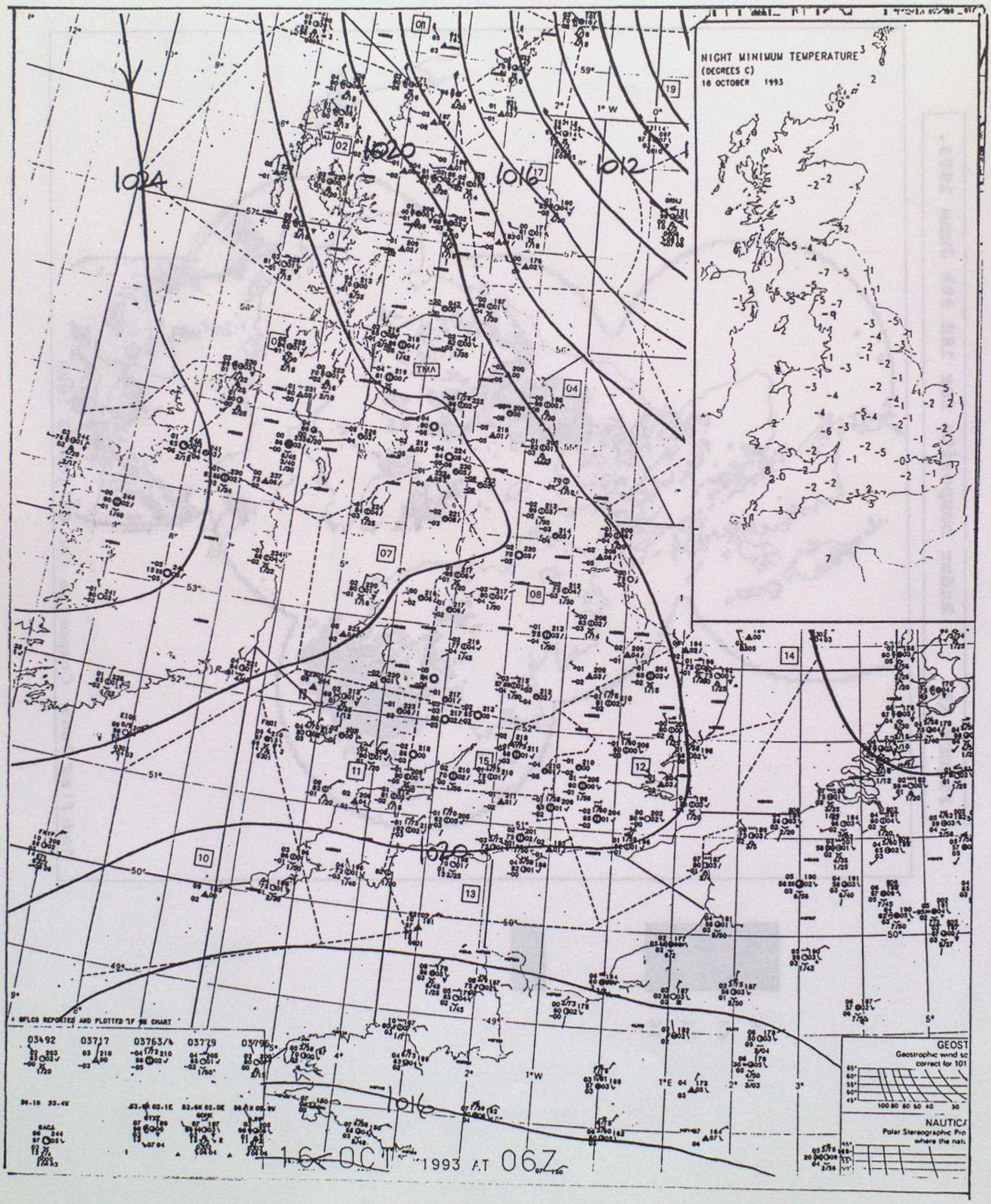
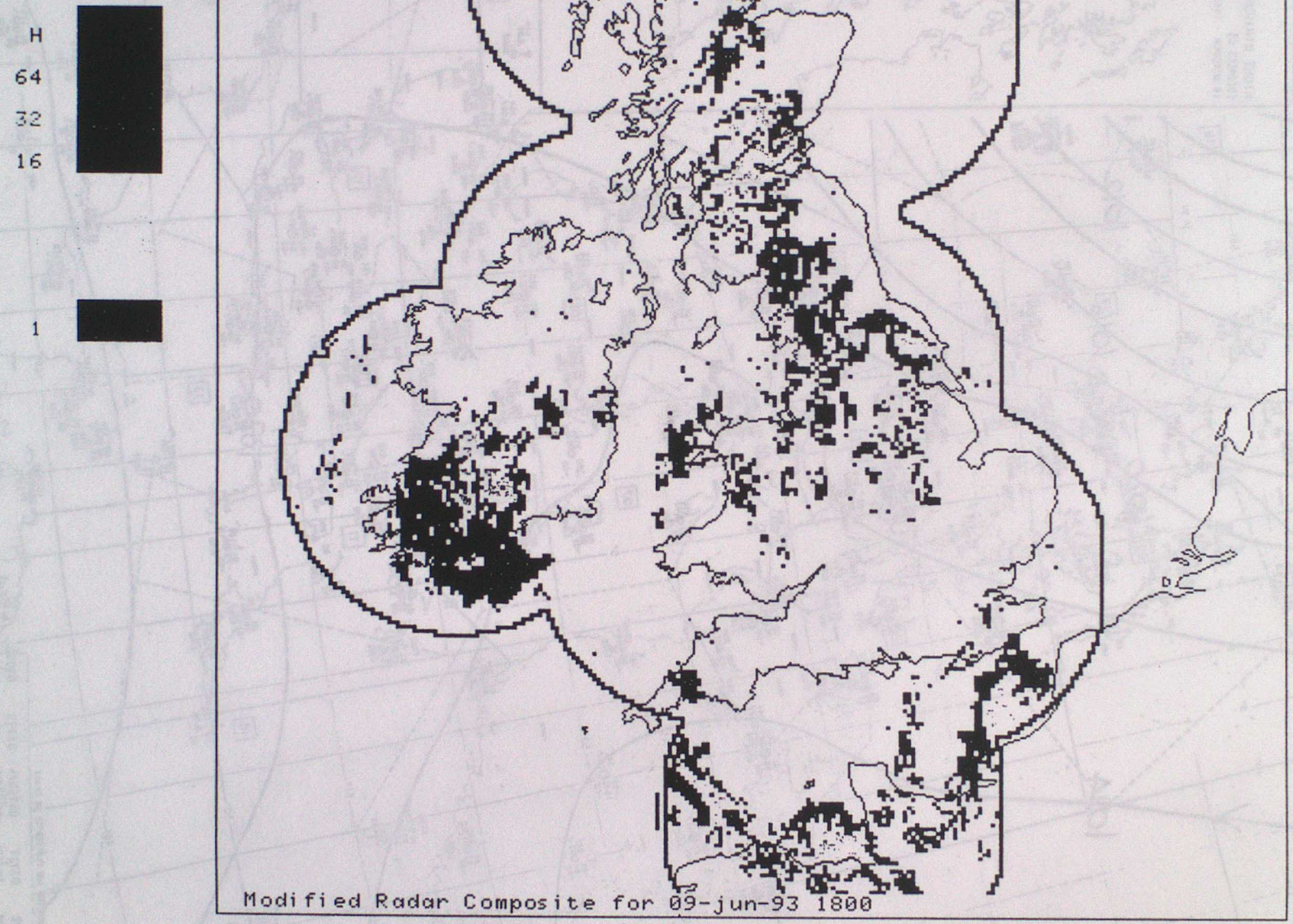


**Figure 19** **Radar composite for 18Z 9th June 1993.**



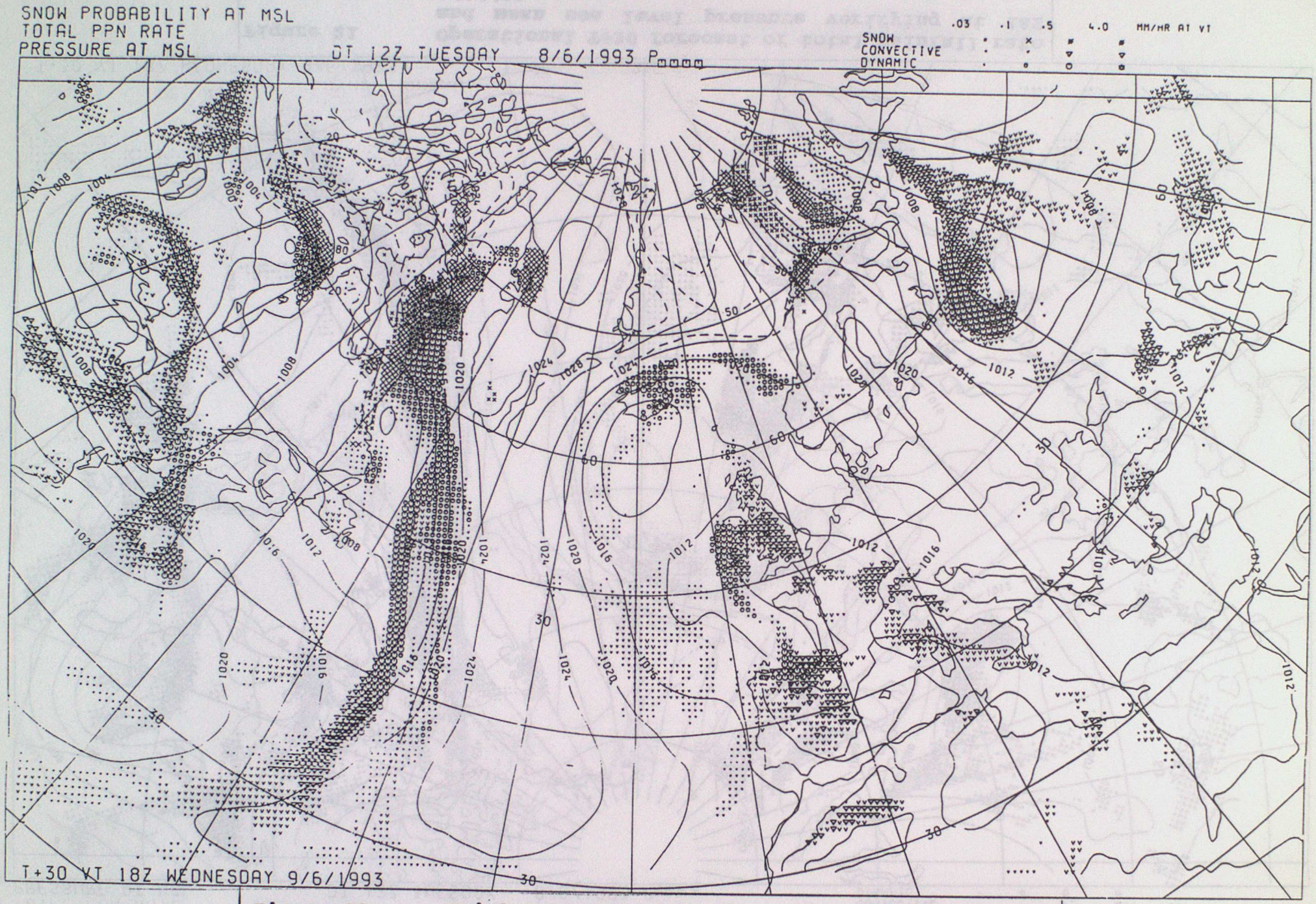



**Figure 20** **Trial T+30 forecast of total rainfall rate and mean sea level pressure verifying at 18Z 9/06/93.**

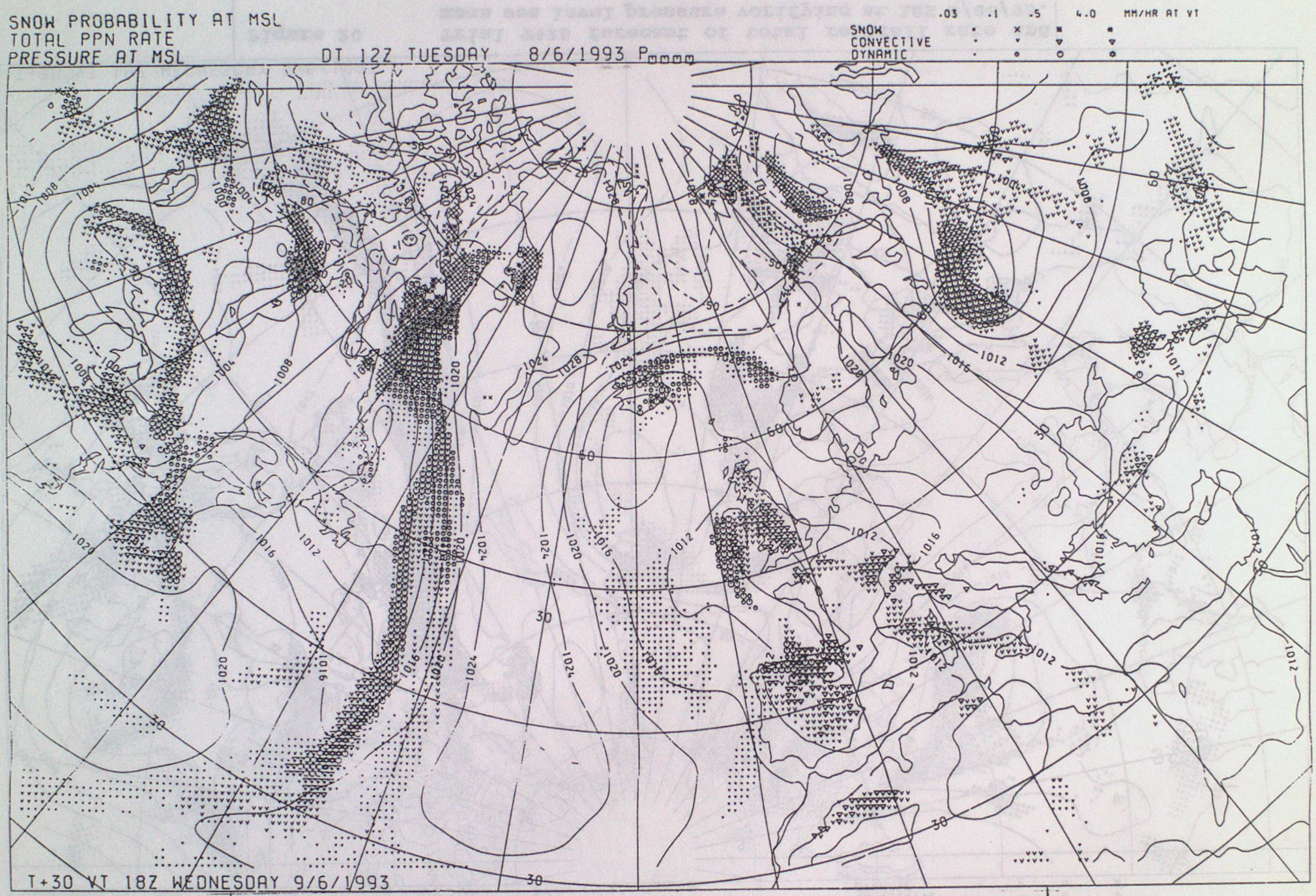
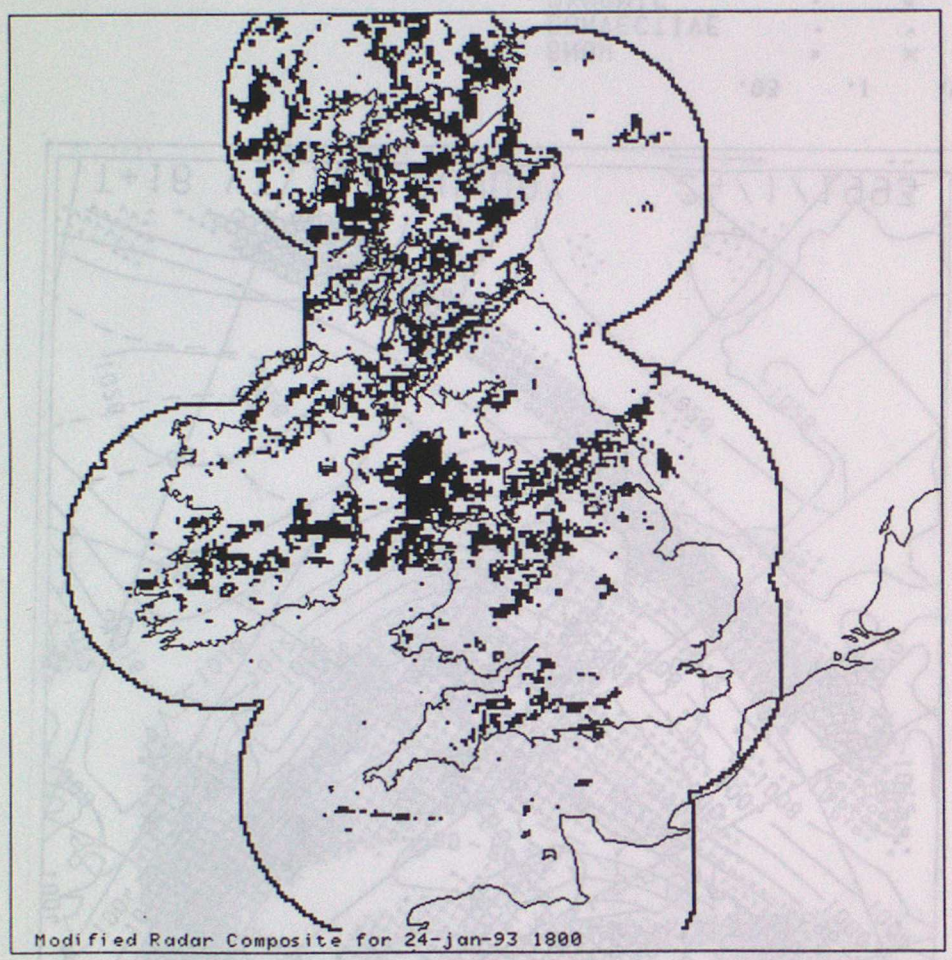



**Figure 21** **Operational T+30 forecast of total rainfall rate and mean sea level pressure verifying at 18Z 9/06/93.**



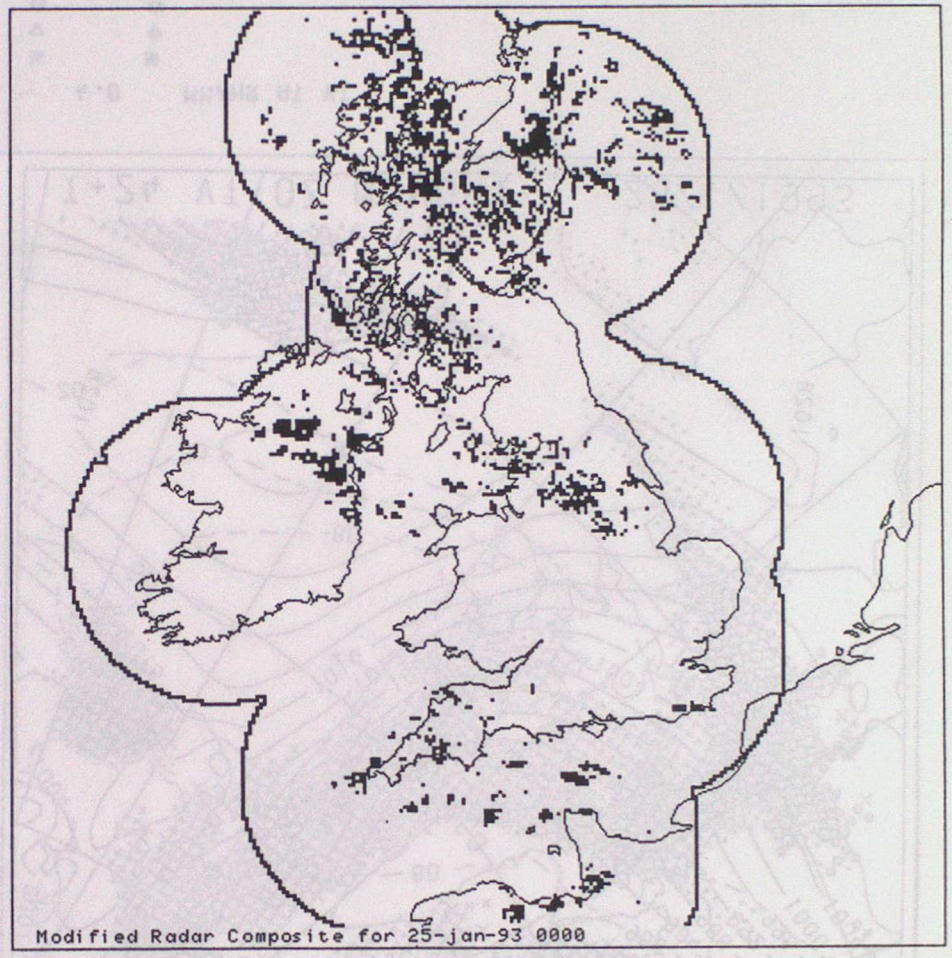




**Figure 22a** Radar composite for 18Z 24/01/93
**Figure 22b** Radar composite for 00Z 25/01/93

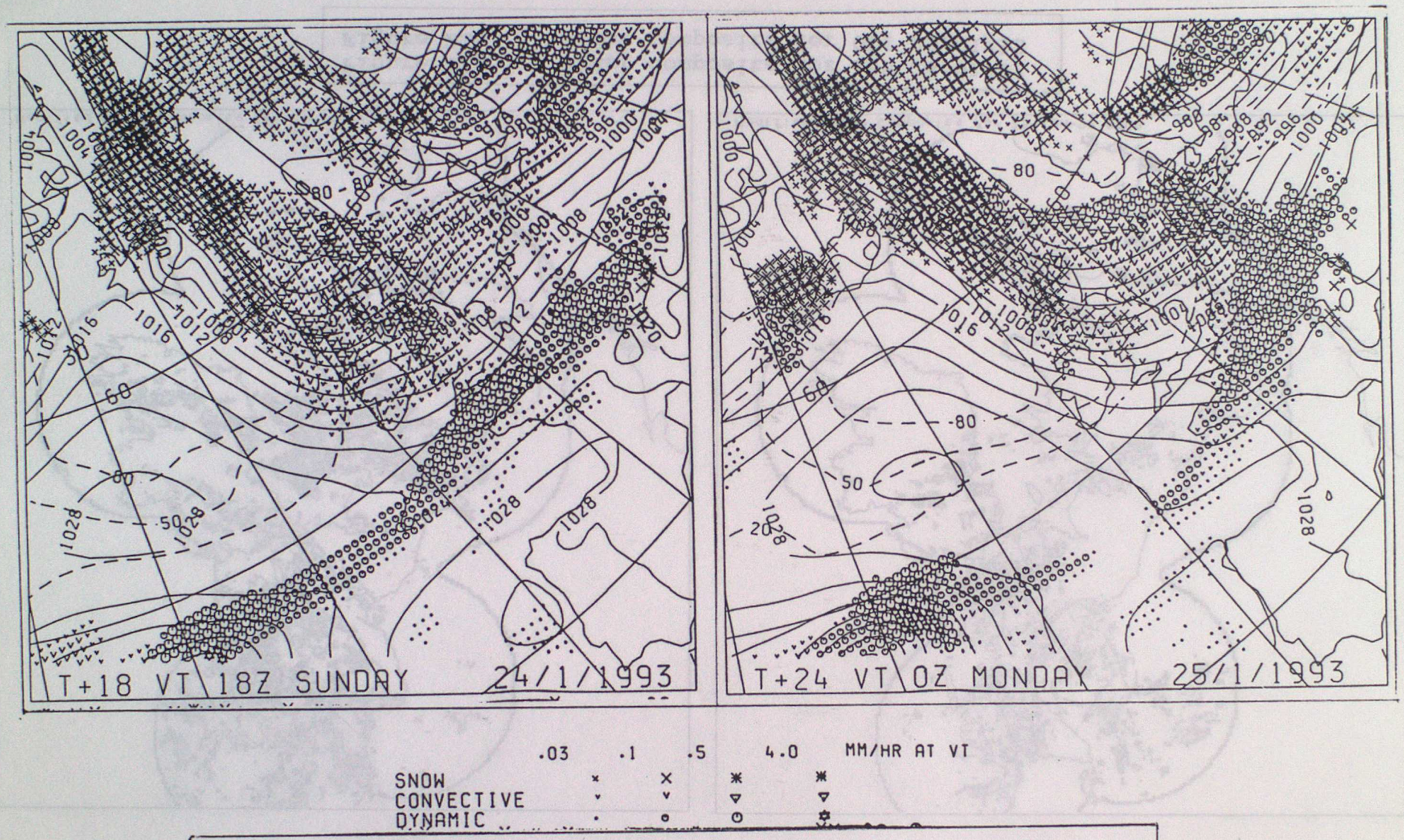



**Figure 24** **Operational T+18/24 forecasts of mean sea level pressure and total precipitation rate, verifying at 18Z 24/01/93 and 00Z 25/01/93 respectively.**

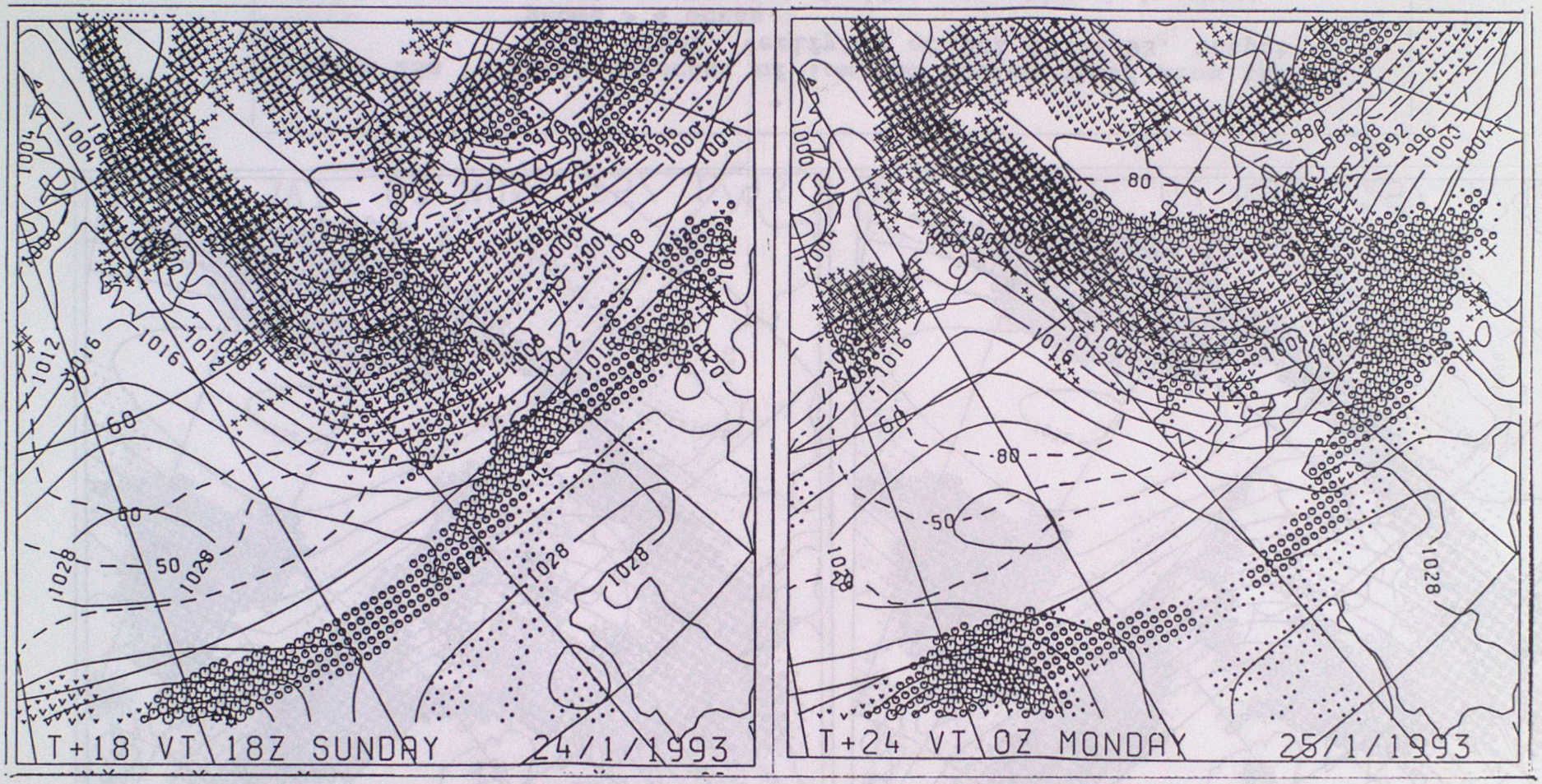



**Figure 23** **Trial T+18/24 forecasts of mean sea level pressure and total precipitation rate, verifying at 18Z 24/01/93 and 00Z 25/01/93 respectively.**

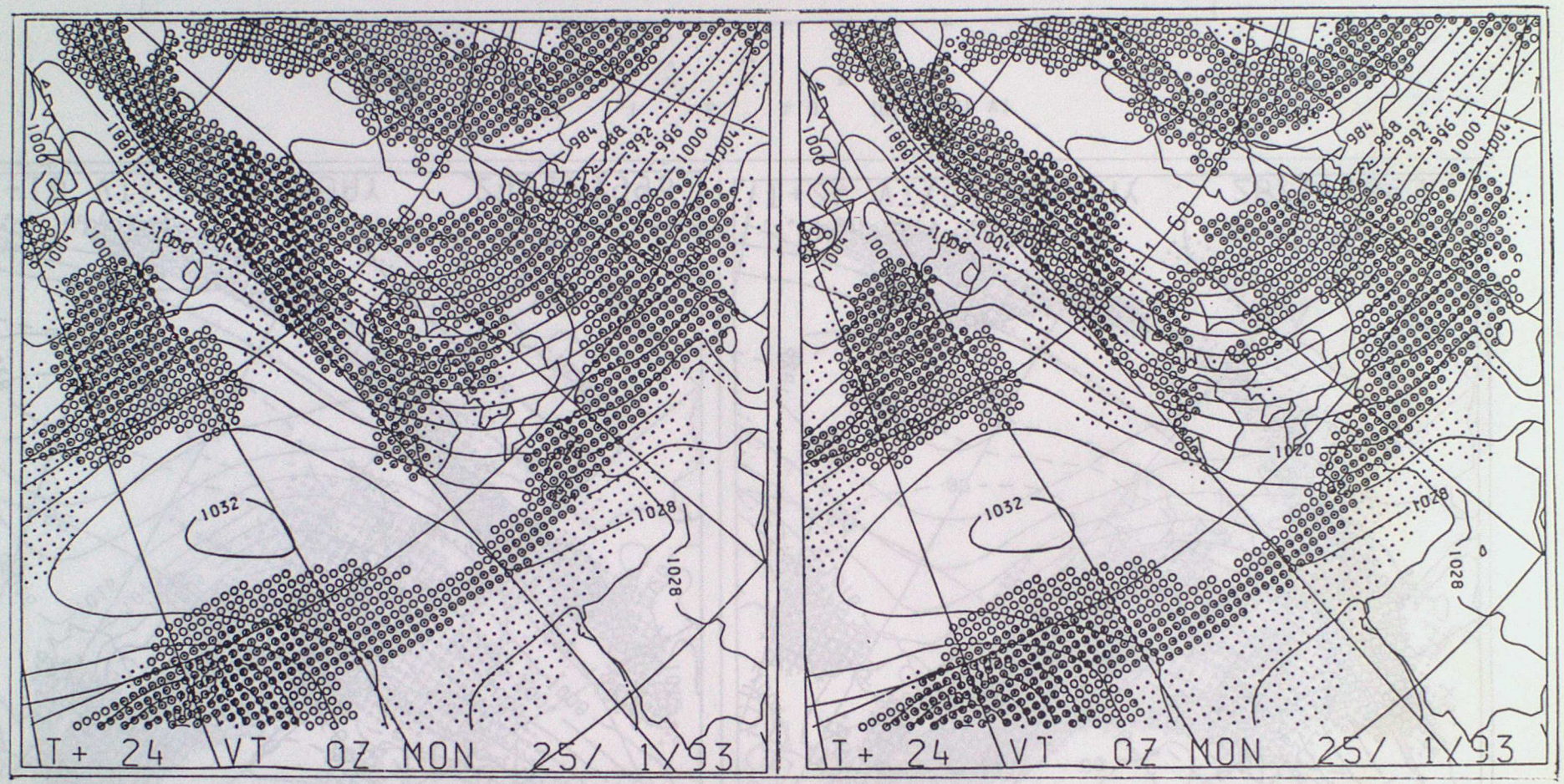



**Figure 25a** T+24 forecast of low and medium cloud from the trial model, verifying at 00Z 25/01/93. Output shows > 4 octas.

**Figure 25b** As Figure 25a but for the operational forecast.